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SOIL SAMPLING PLAN

DICO OIL
1845 East Willow Street
Signal Hill, California

Meredith & Associates, Inc.
M&A

Scientific, Environmental Engineering, and Regulatory Consultants

M&A Project No. MA-2003-123

SOIL SAMPLING PLAN

**DICO OIL
1845 East Willow Street
Signal Hill, California**

Prepared for:

**US ENVIRONMENTAL PROTECTION AGENCY
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December 10, 2003

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1.0 INTRODUCTION

1.1 PURPOSE

On September 3, 2003, Dico Oil Company (Dico) was issued a "Unilateral Administrative Order for the Performance of a Removal Action" (Order). At the time of the Order, Dico was not operational and all hazardous waste substances located on-site had been left in-place. The purpose of the Order is to mitigate threats to human health and the environment due to on-going releases or threats of releases of hazardous substances.

Meredith & Associates (M&A) was retained by Dico to prepare a Soil Sampling Plan (SSP) to comply with the soil sampling provisions of this Order. The purpose of the SSP is to characterize the nature and extent of contamination in soil beneath the site as the preliminary step in conducting a removal action under the Order.

1.2 SITE LOCATION

Dico is located at 1845 East Willow Street in Signal Hill, Los Angeles County, California (hereinafter, the Site). A site vicinity map is provided as Figure 1. The coordinates of the Site are N33° 48' 21.7" and W118° 10' 07.1". The surrounding properties consist of vacant land and commercial developments, as shown in Figure 2.

1.3 PROJECT BACKGROUND

The project background is summarized from the "Findings of Fact" identified in the Order and the Action Memorandum, dated October 3, 2003, prepared by Craig Benson, On-Scene Coordinator for the United States Environmental Protection Agency (USEPA).

Dico operated an oil and recycling facility from 1960 to 1995. While in operation, Dico blended oils that contained varying amounts of water and sediment to create a marketable fuel. Asphalt emulsions, crude oil, diesel fuels, jet fuel, kerosene and Stoddard solvents, waste oils, and light to heavy fuel oils contaminated with water and solids were accepted from various sources and placed into six steel above-ground storage tanks (ASTs) for processing and blending. The "recycled oil" was then sold through brokers primarily to the bunker oil market as ship fuel. Dico reportedly purchased, processed and re-sold between 2-3 million gallons of oil per year.

The Site is located in a largely commercial zone as indicated below:

- North of the Site is a prefabricated industrial/office park
- East of the Site are two residences, which are located on property owned by Dico. According to a representative of Dico, the renters in both houses were asked to vacate the property. The houses will be demolished and the property will be used for industrial purposes. According to representative of Dico, the property is zoned for commercial use
- South of the Site is a retail business and associated parking lot
- West of the Site is an undeveloped lot used primarily for oil production by Signal Hill Petroleum.

M&A conducted a site reconnaissance on November 17, 2003. The Site is approximately 19,000 square feet and consisted of a former tank farm, and a truck pad. The tank farm had three large steel ASTs (15 feet diameter, 16 feet high) and associated above-ground and below-ground piping. The facility has not been in operation since the mid-1990s.

1.4 SITE AND AREA LITHOLOGY

Based on data summarized in the "RCRA Facility Assessment Report for Dico Oil Corporation", the Site is underlain by silty sand to a depth of 9 feet below ground surface (bgs). Poorly cemented sand was encountered at a depth of nine to eleven feet bgs. Loose sand was encountered at 11 to 13 feet bgs, and poorly indurated sand was encountered from 13 to 16 feet bgs.

1.5 AREA HYDROLOGY

As summarized in the Action Memorandum, groundwater is estimated to be present at a depth of 150 to 200 feet beneath the facility. The Memorandum also stated that it is unlikely that significant groundwater contamination resulted from previous Site activities.

1.6 CONTAMINANTS PREVIOUSLY IDENTIFIED AT THE SITE

Based on the Action Memorandum prepared by EPA for the Site, six previous soil sampling events were conducted at the Site and are listed in Appendix 2 of the Action Memorandum, Table 1: Historical Data for the Dico Oil Co. Site. The actual reports from which these data were compiled were not readily available for M&A's review. The reports are listed in Table 1, along with the compounds detected. Based on the historical data, the following contaminants have been identified at the Site:

- The maximum Total Petroleum Hydrocarbons (TPH) concentration was 44,000 milligrams per kilogram (mg/kg).
- The maximum TPH as oil was 680,000 mg/kg.
- The maximum TPH as diesel was 24,000 mg/kg.
- The maximum PCB concentration was 4,400 mg/kg.
- Numerous Volatile Organic Compounds (VOCs) were detected at relatively low concentrations.
- Numerous Semi Volatile Organic Compounds (SVOCs) were detected at relatively low concentrations
- The maximum lead concentration was 2,300 mg/kg.
- The maximum chromium concentration was 484 mg/kg.

1.7 ORDER REQUIREMENTS

Based on the analytical results from the 2003 soil sampling effort, the lead, chromium, and PCB concentrations were considered hazardous substances as defined by Section 101(14) of CERCLA. EPA issued an Order to mitigate the hazardous substances at the Site.

The following activities were required by the Order:

- a) Relocate non-hazardous vehicles and other equipment from the existing truck pad and provide for an unrestricted access corridor from the facility gate to the tank farm area
- b) Sample and characterize all containerized materials, including tank sludge, content of piping systems, and any non-bulk containers on-site

- c) Segregate all hazardous substances
- d) Characterize, dismantle and remove all tanks and vats from the Site, including appurtenant tank farm structures, berm soils, contaminated concrete, vegetation and debris
- e) Submit a Soil Sampling Plan to assess Site soils for contamination with hazardous substances, including soils classified as PCB remediation waste as defined by 40 Code Federal Regulations (CFR) Part 761. The assessment shall characterize the zone extending from the surface to a minimum of five (5) feet below ground surface, except as necessary to characterize the extent of soil contamination to the point at which either the contamination terminates or first groundwater is reached
- f) Excavate and remove Site-contaminated soils until the conditions of the soil cleanup verification and analysis are achieved. The excavation must be backfilled with clean fill, compacted, and graded, restoring its original condition
- g) All hazardous substances shall be disposed of in accordance with Section 121(d)(3) of CERCLA, 42 U.S.C. 9621(d)(3) and the EPA "Procedures for planning and implementing off-site response actions," promulgated at 40 C.F.R. Part 300.400.

1.8 DOCUMENTS ASSOCIATED WITH THE ORDER

On September 17, 2003, Dico retained The Reynolds Group (Reynolds) to develop and implement a Work Plan in response to provisions a, b, c and d of the Order. Dico retained Consolidated Waste Industries, Inc. (CWI) to perform the actual physical work of packaging, sampling, transporting, and disposal of the ASTs and piping. The following documents were prepared by Reynolds:

- Work Plan, dated September 17, 2003. This work plan included a Phase I – Top Side Clean-up, demolition, and removal action, and a Phase II Characterization, remediation and confirmation
- Supplement #1 to the Work Plan dated September 17, 2003. This submittal primarily included the Site Health and Safety Plan by Consolidated
- Supplement #2 to the Work Plan dated September 17, 2003. This submittal included a revision to Health and Safety Plan
- Supplement #3 to the Work Plan dated September 17, 2003. This submittal described how the bulk waste sampling from the ASTs will be performed, and how the manifest labeling will be completed
- Supplement #4 to the Work Plan dated September 17, 2003. This submittal describes how the structures will be dismantled, and how the ASTs will be certified by a Marine Chemist and removed
- Soil Sampling Plan, dated September 24, 2003. This plan listed the general requirements which will be included in the final Soil Sampling Plan
- Supplement #1 (dated November 12, 2003) to the Soil Sampling Plan dated September 24, 2003. This supplement describes how the berm will be sampled. This supplement is intended to be performed concurrently with Supplement #4 of the Work Plan
- Supplement #1 (dated November 14, 2003) to the Soil Sampling Plan dated September 24, 2003. This submittal describes the use of the Enslys field kit for PCB analysis.

1.9 WORK COMPLETED

The above-ground structures have been removed. Most of the berm has been removed and contained within covered roll-off bins, and the bulk wastes from the ASTs were contained within twenty 55-gallon drums and one roll-off bin. The bins and drums containing the berm and bulk waste materials were stored on-site pending appropriate disposal. The bin containing the metal above-ground structures have been sent to a metal recycling facility.

On November 19, 2003, Dico retained M&A to sample the drums and bins for disposal and to prepare a Soil Sampling Plan for the residual soil. On November 21, 2003 M&A submitted Supplement #5 to the Workplan dated September 17, 2003, which documented the profiling of the wastes from the bins and drums. On November 25, 2003, the drums and roll-off bins were sampled as described in Supplement #5. The drums and bins will remain on-site pending the analytical results.

The only remaining structures associated with the former oil blending operations are concrete slabs. All other structures have been removed.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

M&A will serve as the Project Coordinator, overseeing the work. Mr. Keith G. Farrell, a Certified Engineering Geologist will be the Project Manager, and will be assisted by Ms. Lynn Edlund, a Registered Geologist, and Mr. Roger McCracken, the field supervisor.

The soil samples will be collected by M&A.

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The soil samples will be submitted to the following state certified laboratory:

ASSOCIATED LABORATORIES (ELAP Cert 1338)
806 North Batavia
Orange, California 92668
(714) 771-6900
Fax (714) 538-1209

or

ENVIRO-CHEM, INC (ELAP Cert 1555)
1214 E. Lexington Avenue
Pomona, California 91766
(909) 590-5905
Fax (909) 590-5907

3.0 FIELD SAMPLING PROGRAM

3.1 PROJECT OBJECTIVES

The objectives of the field sampling program are as follows:

- Assess Site soils for contamination with hazardous substances in accordance with the guidelines provided in "Site Characterization Sampling for PCB Remediation Waste" (40 CFR 761.260, Subpart N). PCBs, chromium, and lead were specifically identified in the Order as "hazardous substances" associated with the Site. In addition, Site soils contained elevated concentrations of TPH.
- Provide a report documenting the areas of hazardous substances, which will be used to identify the amount of material to be excavated and removed from the Site.

3.2 CLEANUP GOALS

The Action Memorandum identified 1 milligram per kilogram (mg/kg) as the cleanup level for PCBs based on the "High occupancy areas" cleanup level defined in 40CFR 761.61.

M&A proposes that the lead and chromium cleanup levels be based on EPA Region 9 Preliminary Remediation Goals (PRGs) for industrial soil, dated October 2002, which are 750 mg/kg for lead and 450 mg/kg for chromium. The future redevelopment of the Site as an industrial facility is consistent with the use of industrial PRGs.

Cleanup criteria for TPH will be based on the Los Angeles Regional Water Quality Control Board's *Interim Site Assessment and Cleanup Guidebook*, which takes into account site-specific conditions, such as depth to groundwater and hydrocarbon chain length. For example, for a groundwater depth between 20 to 150 feet bgs, the RWQCB cleanup criteria for TPH as diesel (carbon range C13-22) is 1,000 mg/kg and the cleanup criteria for TPH in the oil (C23-32) is 10,000 mg/kg.

3.3 PROPOSED SOIL SAMPLING LOCATIONS

The field investigation will consist of the collection of concrete samples from six locations and soil matrix samples from 83 locations. Proposed sampling locations are shown on Figure 3.

3.4 RATIONALE FOR SAMPLE NUMBERS, LOCATIONS, DEPTHS AND ANALYSES

Both concrete and soil samples will be collected. The concrete will be sampled to determine whether a portion, or all of the concrete, once removed, must be managed as a hazardous or non-hazardous waste. Results from the soil sampling effort will be used 1) to assess the site soils for contamination with hazardous substances and 2) to develop a removal action plan for excavation and off-site disposal. Both the concrete and soil sampling rationales are described below.

3.4.1 Concrete Sampling Rationale

A total of six concrete samples (CON-1 to CON-6) will be collected from six locations, as shown on Figure 3. The concrete will be divided into two areas: the approach (the concrete slab adjacent to, and north from, the truck loading/unloading area), and the truck loading/unloading area. Three locations along the centerline of the two areas will be sampled. The concrete will be cored in accordance with ASTM C-42/C -42M-03, section 5.2. Using the

appropriate tools (i.e., sledge hammers, chisels, etc.) a sample will be removed from the center of the core. The sample will be placed in a labeled wide-mouth glass jar, or similar container.

Concrete samples located along the approach (CON-1 to CON-3) are intended to assess possible impacts from trucks during ingress and egress and other on-site activities. The concrete samples located in the truck loading/unloading area (CON-4 to CON-6) are intended to assess possible impacts from releases from trucks and transfer equipment during unloading of waste oil and loading of recycled product. Prior to analysis, the laboratory will composite the three discrete samples, from each area into a single composite sample. The composite concrete samples will be analyzed for the following parameters:

- Total Petroleum Hydrocarbons – USEPA Method 8015M
- Polychlorinated biphenyls -- USEPA Method 8082
- Lead and Chromium -- USEPA Method 6010/7000.

A duplicate sample will be prepared from one of the composites for quality assurance/quality control (QA/QC) purposes. The duplicate sample also will be analyzed for the above parameters.

3.4.2 Soil Sampling Rationale

Soil sampling will be performed in accordance with 40 CFR 761, Subpart N. To assess the extent of contamination at the site, soil borings will be installed at approximately 83 locations as shown on Figure 3. Depending on access, borings will be installed using either a push-drive rig (i.e., Stratoprobe, Geoprobe, etc.) or manually using a hand auger or similar equipment to a total depth of 5 feet bgs. All soil samples will be collected from depths of 0.5 foot, 2.5 feet, and 5.0 feet bgs. Sample identification will be the boring location followed by the sample depth (i.e., Sample No. B1-0.5 is from boring B1 at 0.5-feet bgs)

In areas where imported fill is present (such as in the northern end of the tank farm), soil borings will be advanced to 5-feet below the bottom of the fill material. If the fill material extends beyond 5.0-feet bgs, soil samples collected at the 0.5, 2.5, and 5.0-foot depth intervals in the fill, and soil samples will also be collected at a depth of 2.5-feet and 5.0-feet below the base of the fill material.

As shown on Figure 3, the soil borings will target soil beneath the concrete approach (B-1 to B-3), the truck loading/unloading area (B-4 to B-6), the former tank farm (B-7 to B-56), the former drum storage area (B-57 to B-80), and along the eastern edge of the site (B-81 to B-83). The number of anticipated samples to be collected at each location is listed in Table 2 and is summarized below:

- Beneath concrete (B-1 to B-6). Eighteen (18) samples will be collected. The 0.5-foot and the 2.5-foot soil samples will be analyzed as discrete samples. The 5-foot soil sample will be placed on hold. If the contaminants exceed the clean-up criteria at a depth of 2.5 feet, then the 5-foot soil sample will be analyzed. If the clean-up criteria are not exceeded in the 2.5-foot depth sample, the deeper sample will not be analyzed.
- Within the former tank farm (B-7 to B-56) – 150 samples, analyzed as composites (see Table 2)
- Former drum storage area (B-57 to B-80) – 72 samples, analyzed as composites (see Table 2)
- Eastern edge of the site (B-81 to B-83). Nine samples will be collected. The 0.5-foot and the 2.5-foot soil samples will be analyzed as discrete samples. The 5-foot soil sample will be placed on hold. If the

contaminants exceed the clean-up criteria at a depth of 2.5 feet, then the 5-foot soil sample will be analyzed. If the cleanup criteria are not exceeded in the 2.5-foot depth sample, the deeper sample will not be analyzed.

In accordance with 40 CFR 761.283 samples will be collected within the former tank farm area and drum storage area using a grid interval of 3-meters (10-feet). A boring will be advanced within the center of each grid interval. Approximately 222 soil samples will be collected. The soil samples then will be composited in the laboratory, as shown on Table 2. The soil compositing will be based on the following three criteria: collection from the same depth (i.e., 0.5-feet bgs, 2.5-feet bgs, 5.0-feet bgs, etc.), similar lithology, and a similar or same point source of contamination (i.e., the location of the former ASTs, or the pipe trench, or drum storage area).

Approximately 39 composite soil samples will be analyzed from locations B-7 through B-80 and 18 discrete soil samples (B-1 through B-6 and B-81 to B-83). All samples will be analyzed for the following parameters:

- Total Petroleum Hydrocarbons diesel and oil – USEPA Method 8015M
- Polychlorinated biphenyls (PCBs) – USEPA Method 8082
- Lead and Chromium – USEPA Method 6010B/7000

Additional soil samples may be added to the field investigation beyond the 5.0-feet depth, in response to the visual inspection soil cuttings or detection of elevated VOCs during drilling or sample collection. The added samples will be collected at two foot intervals, until visible contamination is no longer present, or as appropriate to achieve the cleanup goals at that location. Also additional samples may be required after review of analytical data. Any additional samples will be analyzed as discrete samples for the parameters listed above.

If one of the composite samples exceeds the clean-up criteria, additional samples may be needed to better define the extent of contamination. The grid will be extended, as necessary, in order to define the extent of contamination to cleanup goals. For example, if the composite sample “Comp 1” exceeds the cleanup criteria at a depth 0.5 feet, the grid will be extended to the north and west, and an additional six samples will be collected from a depth of 0.5 feet from the center of each new grid which adjoins the composited square.

All soil samples will be archived at the laboratory. If additional soil samples are needed to better assess an area, the soil sample(s) will be retrieved and analyzed, within appropriate holding times.

Duplicate composite samples will be prepared by the laboratory at a rate of approximately 10%. Duplicate soil samples will be analyzed for the same parameters as the primary samples.

3.5 FIELD METHODS AND PROCEDURES

The methods and procedures that will be used to collect soil vapor and soil matrix samples are described in the following sections. Additional details regarding field methods and procedures are described in the Quality Assurance Program Plan (QAPP), which is included in Appendix A.

3.5.1 Sample Collection Procedures

Soil borings will be advanced using a push-drive rig, such as a Stratoprobe or GeoProbe 4220 system (or equivalent), or by manual means using a hand auger. Based on the Site reconnaissance, all of the soil investigation locations are in open areas and limited access equipment will not be required. The soil samples will be collected

using either acetate sleeves or brass sleeves. Once the desired sample depth is reached, the soil sample will be collected within the sleeve and retrieved from the borehole. Immediately upon retrieval, the ends of the sleeves will be covered with Teflon tape and polyurethane caps, labeled, and stored in a cooled ice chest. M&A's Standard Operating Procedures (SOPs) for *Soil Matrix Sampling and Logging* are included with the QAPP in Appendix A. A push-drive drill rig does not generate soil cuttings during the soil sample collection. If manual means are used to advance the borings, the generated cuttings and associated decon water will be placed in an appropriately labeled drum. The boreholes will be backfilled with bentonite pellets.

During soil sampling, an organic vapor analyzer (OVA) or photoionization detector (PID) field instrument will be used to monitor the presence and level of VOC vapors in the samples and to monitor the worker's breathing zone for health and safety protection. Soil samples also will be visually inspected by the field geologist for logging purposes. The geologist will note locations where fill is present.

Laboratory duplicate soil samples will be collected at the rate of approximately 10%. Additionally, equipment blanks will be collected at the rate of one per day. Duplicate samples and equipment blanks will be analyzed for the same parameters as the primary sample.

3.5.2 Sample Containers, Preservatives, Packaging, and Shipment

Sample containers, preservatives, and holding times are summarized in Table 3 and in the site-specific QAPP (see Appendix A). Soil matrix samples will be collected in acetate or metal sleeves (i.e., the "sample container"). They will be secured with Teflon sheets, capped, labeled, and stored in a cooled ice chest to maintain a target sample temperature of 4 °C.

3.5.3 Sample Documentation

Sample documentation includes field logbooks, boring logs, chain-of-custody records, and photographs. Each of these is discussed below.

3.5.3.1 Field Logbooks

Field logbooks will document where, when, how, and from whom any vital project information was obtained. Logbook entries will be complete and accurate enough to permit reconstruction of field activities. Logbooks will be bound with consecutively numbered pages. Each page will be dated and the time of arrival on-site noted. All entries will be legible and signed by the individual making the entries. Language will be factual and objective. If an error is made, corrections will be made by crossing a line through the error and entering the correct information. Corrections will be dated and initialed. No entries will be obliterated or rendered unreadable.

At the minimum, entries in the field logbook will include following for each sample date:

- Property name and address
- Recorder's name
- Team members and their responsibilities
- Time of arrival/entry on site and time of departure
- Other personnel onsite

- A summary of any onsite meetings
- Deviations from sampling plans and site safety plans
- Changes in personnel and responsibilities, as well as reasons for the changes
- Levels of safety protection
- Calibration readings and identification information for any equipment used.

3.5.3.2 Boring Logs

A lithologic description of the materials encountered will be noted in the boring logs for the 5-foot borings. Due to the overall shallow sampling depths, a geologic cross-section will not be generated. Soils will be classified in accordance with the Unified Soil Classification System (USCS), and descriptions will include soil type, particle size and distribution, color, moisture content, and evidence of contamination (discoloration, unusual odors, etc.). The soil samples will be screened for the presence of elevated organic vapor concentrations using an organic vapor analyzer (OVA), and the measurements will be recorded on the boring log.

3.5.3.3 Chain-of-Custody Records

At the conclusion of each work day, soil samples will be transported to the laboratory under chain-of-custody control. M&A's chain-of-custody procedures are described in M&A's SOPs Sample Handling and Preservation which is included with the QAPP in Appendix A.

3.5.3.4 Photographs

Photographs will be taken at sample locations and at other on-site areas of interest, if warranted to verify information entered in the field logbook.

3.6 ANALYTICAL PROGRAM

M&A plans to use Associated Laboratories (Orange, California) or Enviro-Chem (Pomona, California) for the analysis of samples. Both laboratories are State-certified laboratories. All primary and duplicate soil samples will be analyzed by one or both of these laboratories or their subcontract laboratories for the following parameters:

- Total Petroleum Hydrocarbons, diesel and oil – USEPA Method 8015M
- Polychlorinated Biphenyls (PCBs) – USEPA Method 8082
- Lead and Chromium – USEPA Method 6010/7000.

3.7 EQUIPMENT DECONTAMINATION

Any equipment that comes into contact with potentially contaminated material will be decontaminated to assure the quality of the samples collected. Sampling devices used for the collection of soil samples will be decontaminated between uses by scrubbing them in an Alconox cleaning solution, using a brush when necessary, followed by clean water and deionized water rinses.

3.8 FIELD VARIANCES

Because conditions in the field can vary, it might be necessary to implement minor modifications to the sampling program presented in this SSP. When appropriate, the USEPA will be notified of the modifications and a verbal approval will be obtained before implementing the modifications. Any modifications to the approved plan will be documented in the final report.

3.9 QUALITY ASSURANCE/ QUALITY CONTROL (QAPP)

QA/QC measures will be employed to ensure the reliability and comparability of all data generated during the field investigation. A Site-specific QAPP for this investigation is included as Appendix A. The QAPP provides specific descriptions of the field and laboratory procedures to be employed for verifying and maintaining performance quality for collection of environmental samples and subsequent chemical analysis. The QAPP sets forth the policies, procedures, and activities for the identification and documentation of the precision, accuracy, completeness, and representativeness of the data during the performance of the investigation. Target laboratory reporting limits for soil analytical results also are summarized in the QAPP.

3.10 HEALTH AND SAFETY PLAN

A Site-specific Health and Safety Plan (HASP) has been prepared for use during the planned field activities (see Appendix B). The HASP is consistent with the requirements of the Code of Federal Regulations. (CFR) and the California Code of Regulations (CCR) pertaining to the requirements for health and safety at hazardous waste sites (specifically, 29 CFR 1910.120 and 8 CCR 5192). The HASP includes information related to the following:

- Identification and description of potentially hazardous substances that may be encountered during the field investigation.
- Description of personal protective equipment and clothing appropriate for the field investigation activities (Level D protection is anticipated for the planned field activities).
- Identification of measures that would be implemented in the event of an emergency, including a map that shows the route to the nearest emergency hospital.

M&A field personnel and subcontractors will review the HASP prior to commencing field work. A health and safety meeting (i.e., "tailgate" meeting) will be conducted by the Site Health and Safety Officer each morning, and a record of meeting attendance will be maintained. All on-site personnel will be required to sign the daily health and safety briefing form.

4.0 REPORT PREPARATION

Once the field program has been completed, the analytical results will be compiled to identify areas of PCBs, chromium, lead, and TPH concentrations which exceed the cleanup goals defined in Section 3.2.

The contents of the report will include the following:

- Executive summary
- Site description

- Background
- Environmental setting
- Sampling activities and results
- Conclusions
- Supporting documentation

The report will be prepared by, or under the direct supervision of, a California Engineering Geologist, a California Registered Geologist, or Professional Engineer who will review and sign the report indicating responsibility for its content.

The information provided in this report will be used to identify areas to be remediated by excavation. Following excavation, confirmation sampling will be required as directed in (CFR) Part 761.

TABLES

Table 1. Summary of Historic Reports and Contaminants Detected at Dico Oil

Year	Report Title	TPH (mg/kg)	PCBs (mg/kg)	Lead (mg/kg)	Chromium (mg/kg)	VOCs (ug/kg)	SVOCs (mg/kg)
1988	Geotechnical Report, Subsurface Tank Site at 2623 Gardenia Avenue	945.3	-	-	-	-	-
1989	Hazard Appraisal and Recognition Plan	-	180	-	-	-	-
1990	E&E report	44,000	-	340	37	-	-
1994	Visual Site Inspection and Facility Sampling Plan	-	4,400	-	-	-	-
1994	RCRA Facility Assessment Report	29,000	360	2,300	-	benzene -8.7, toluene - 160 ug/kg, ethylbenzene- 27, total xylenes - 142, methylene chloride - 11, tetrachloroethene - 15, isopropylbenzene -1.8, propylbenzene - 3, 1,2,4-trimethylbenzene - 38, 1,3,5- trimethylbenzene - 15, sec-butylbenzene - 4.6, isopropyltoluene - 6.5, 1,2-dichlorobenzene - 1.4, 1,2,4-trichlorobenzene - 114, naphthalene - 24	naphthalene - 4, fluorene - 17, phenanthrene - 45, fluoranthene - 10, pyrene - 19, benzo(a)anthracene - 11, chrysene - 17, benzo(b) fluoranthene - 8, benzo(a)pyrene - 9.6, 2 methyl naphthalene - 130
1994	Environmental Site Assessment and Soil Analyses Report	10,000	4.5	5.7	8.9	acetone - 98, benzene - 48, 2-butanone - 51, ethylbenzene - 570, tetrachloroethene - 190, 1,1,1-trichloroethane - 52, toluene - 1,400, xylenes - 7,500	-
2003	Action Memorandum	680,000 oil 24,000 diesel	27	1,640	484	-	-

TPH - Total Petroleum Hydrocarbons

PCBs - Polychlorinated biphenyls

VOCs - Volatile Organic Compounds

SVOCs - Semivolatile Organic Compounds

mg/kg - milligrams per kilogram

ug/kg - micrograms per kilogram

original 39.

TABLE 2
COMPOSITE SOIL SAMPLE SUMMARY
(Page 1 of 3)

Composite Sample ID	Sample Depth	Discrete Sample IDs	Location/Rational
Comp-1	0.5-feet	B-7-0.5, B-8-0.5, B-9-0.5, B-17-0.5, B-18-0.5, B-19-0.5, B-27-0.5, B-28-0.5, B-29-0.5	Within berm area (tank farm), at north end; fill expected; samples may be within fill material.
Comp-2	2.5-feet	B-7-2.5, B-8-2.5, B-9-2.5, B-17-2.5, B-18-2.5, B-19-2.5, B-27-2.5, B-28-2.5, B-29-2.5	Within berm area (tank farm), at north end; fill expected; samples within native material.
Comp-3	5.0-feet	B-7-5.0, B-8-5.0, B-9-5.0, B-17-5.0, B-18-5.0, B-19-5.0, B-27-5.0, B-28-5.0, B-29-5.0	Within berm area (tank farm), at north end; fill expected; samples within native material.
Comp-4	0.5-feet	B-10-0.5, B-11-0.5, B-20-0.5, B-21-0.5, B-30-0.5, B-31-0.5	Within berm area (tank farm); soil beneath and adjacent to tank T-1
Comp-5	2.5-feet	B-10-2.5, B-11-2.5, B-20-2.5, B-21-2.5, B-30-2.5, B-31-2.5	Within berm area (tank farm); soil beneath and adjacent to tank T-1
Comp-6	5.0-feet	B-10-5.0, B-11-5.0, B-20-5.0, B-21-5.0, B-30-5.0, B-31-5.0	Within berm area (tank farm); soil beneath and adjacent to tank T-1
Comp-7	0.5-feet	B-12-0.5, B-13-0.5, B-22-0.5, B-23-0.5, B-32-0.5, B-33-0.5	Within berm area (tank farm); soil beneath and adjacent to tank T-2
Comp-8	2.5-feet	B-12-2.5, B-13-2.5, B-22-2.5, B-23-2.5, B-32-2.5, B-33-2.5	Within berm area (tank farm); soil beneath and adjacent to tank T-2
Comp-9	5.0-feet	B-12-5.0, B-13-5.0, B-22-5.0, B-23-5.0, B-32-5.0, B-33-5.0	Within berm area (tank farm); soil beneath and adjacent to tank T-2
Comp-10	0.5-feet	B-14-0.5, B-15-0.5, B-24-0.5, B-25-0.5, B-34-0.5, B-35-0.5	Within berm area (tank farm); soil beneath and adjacent to tank T-3
Comp-11	2.5-feet	B-14-2.5, B-15-2.5, B-24-2.5, B-25-2.5, B-34-2.5, B-35-2.5	Within berm area (tank farm); soil beneath and adjacent to tank T-3
Comp-12	5.0-feet	B-14-5.0, B-15-5.0, B-24-5.0, B-25-5.0, B-34-5.0, B-35-5.0	Within berm area (tank farm); soil beneath and adjacent to tank T-3
Comp-13	0.5-feet	B-16-0.5, B-26-0.5, B-36-0.5, B-46-0.5	Within berm area (tank farm); in excavated area at south end
Comp-14	2.5-feet	B-16-2.5, B-26-2.5, B-36-2.5, B-46-2.5	Within berm area (tank farm); in excavated area at south end
Comp-15	5.0-feet	B-16-5.0, B-26-5.0, B-36-5.0, B-46-5.0	Within berm area (tank farm); in excavated area at south end
Comp-16	0.5-feet	B-37-0.5, B-38-0.5, B-39-0.5, B-47-0.5, B-48-0.5, B-49-0.5	Within berm area (tank farm); soil under piping

TABLE 2
COMPOSITE SOIL SAMPLE SUMMARY
(Page 2 of 3)

Composite Sample ID	Sample Depth	Discrete Sample IDs	Location/Rational
Comp-17	2.5-feet	B-37-2.5, B-38-2.5, B-39-2.5, B-47-2.5, B-48-2.5, B-49-2.5	Within berm area (tank farm); soil under piping
Comp-18	5.0-feet	B-37-5.0, B-38-5.0, B-39-5.0, B-47-5.0, B-48-5.0, B-49-5.0	Within berm area (tank farm); soil under piping
Comp-19	0.5-feet	B-40-0.5, B-41-0.5, B-50-0.5, B-51-0.5	Within berm area (tank farm); trench area; soil under piping
Comp-20	2.5-feet	B-40-2.5, B-41-2.5, B-50-2.5, B-51-2.5	Within berm area (tank farm); trench area; soil under piping
Comp-21	5.0-feet	B-40-5.0, B-41-5.0, B-50-5.0, B-51-5.0	Within berm area (tank farm); trench area; soil under piping
Comp-22	0.5-feet	B-42-0.5, B-43-0.5, B-52-0.5, B-53-0.5	Within berm area (tank farm); trench area; soil under piping
Comp-23	2.5-feet	B-42-2.5, B-43-2.5, B-52-2.5, B-53-2.5	Within berm area (tank farm); trench area; soil under piping
Comp-24	5.0-feet	B-42-5.0, B-43-5.0, B-52-5.0, B-53-5.0	Within berm area (tank farm); trench area; soil under piping
Comp-25	0.5-feet	B-44-0.5, B-45-0.5, B-54-0.5, B-55-0.5, B-56-0.5	Within berm area (tank farm); at pit
Comp-26	2.5-feet	B-44-2.5, B-45-2.5, B-54-2.5, B-55-2.5, B-56-2.5	Within berm area (tank farm); at pit
Comp-27	5.0-feet	B-44-5.0, B-45-5.0, B-54-5.0, B-55-5.0, B-56-5.0	Within berm area (tank farm); at pit
Comp-28	0.5-feet	B-57-0.5, B-58-0.5, B-59-0.5, B-60-0.5, B-61-0.5, B-62-0.5, B-63-0.5, B-64-0.5, B-65-0.5	West side of site; former drum storage
Comp-29	2.5-feet	B-57-2.5, B-58-2.5, B-59-2.5, B-60-2.5, B-61-2.5, B-62-2.5, B-63-2.5, B-64-2.5, B-65-2.5	West side of site; former drum storage
Comp-30	5.0-feet	B-57-5.0, B-58-5.0, B-59-5.0, B-60-5.0, B-61-5.0, B-62-5.0, B-63-5.0, B-64-5.0, B-65-5.0	West side of site; former drum storage
Comp-31	0.5-feet	B-66-0.5, B-67-0.5, B-68-0.5, B-71-0.5, B-72-0.5, B-73-0.5	West side of site; former drum storage

TABLE 2
COMPOSITE SOIL SAMPLE SUMMARY
(Page 3 of 3)

Composite Sample ID	Sample Depth	Discrete Sample IDs	Location/Rational
Comp-32	2.5-feet	B-66-2.5, B-67-2.5, B-68-2.5, B-71-2.5, B-72-2.5, B-73-2.5	West side of site; former drum storage
Comp-33	5.0-feet	B-66-5.0, B-67-5.0, B-68-5.0, B-71-5.0, B-72-5.0, B-73-5.0	West side of site; former drum storage
Comp-34	0.5-feet	B-69-0.5, B-70-0.5, B-74-0.5, B-75-0.5, B-76-0.5	West side of site; former drum storage
Comp-35	2.5-feet	B-69-2.5, B-70-2.5, B-74-2.5, B-75-2.5, B-76-2.5	West side of site; former drum storage
Comp-36	5.0-feet	B-69-5.0, B-70-5.0, B-74-5.0, B-75-5.0, B-76-5.0	West side of site; former drum storage
Comp-37	0.5-feet	B-77-0.5, B-78-0.5, B-79-0.5, B-80-0.5	West side of site; former drum storage
Comp-38	2.5-feet	B-77-2.5, B-78-2.5, B-79-2.5, B-80-2.5	West side of site; former drum storage
Comp-39	5.0-feet	B-77-5.0, B-78-5.0, B-79-5.0, B-80-5.0	West side of site; former drum storage

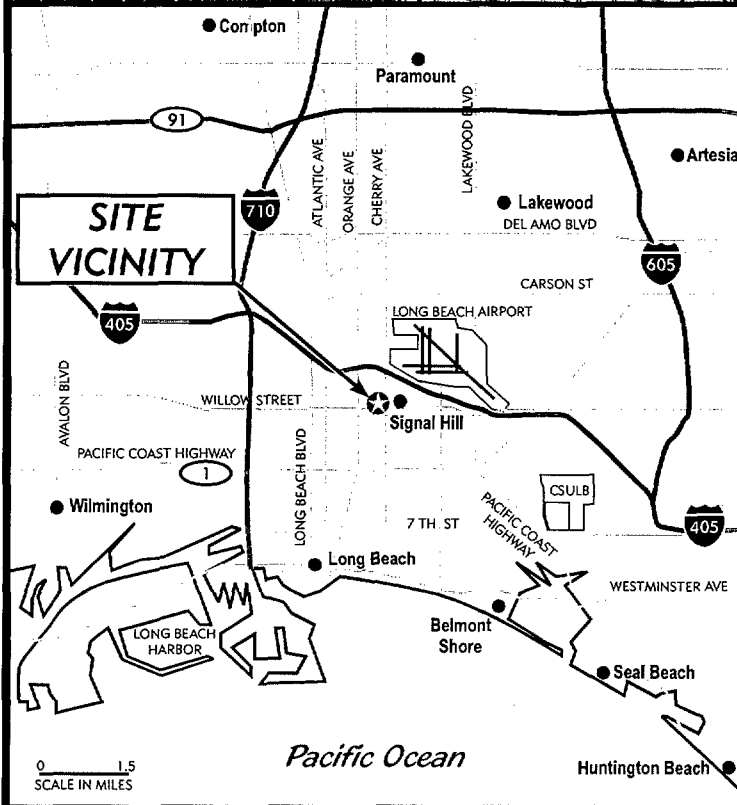
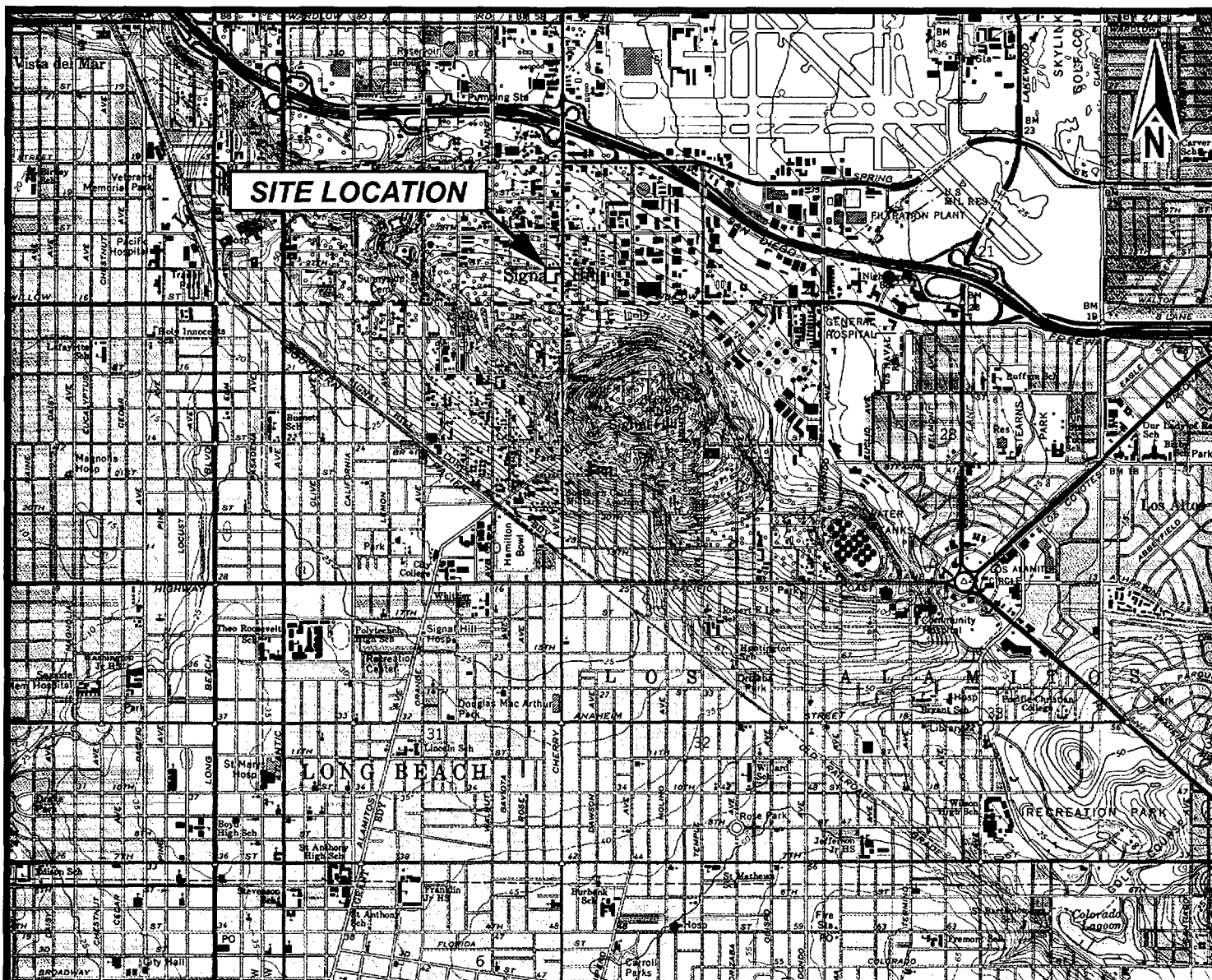
TABLE 3

SUMMARY OF ANALYSES - SOIL MATRIX

Dico Oil Company Site
Signal Hill, California

SOIL MATRIX ANALYSES				
Analyte	Method	Container	Preservative	Holding Time
CAM Metals (see Table 2)	USEPA 6010/7000	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	180 days mercury: 30 days
TPH (extended)	USEPA 8015M	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	14 days to extraction, 40 days to analysis
Polychlorinated Biphenyls	USEPA 8082	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	14 days to extraction, 40 days to analysis

FIGURES



0 1/2 1
 BASE MAP: U.S. Geological Survey 7.5 Minute Series Long Beach, CA
 Quadrangle 1964, Photorevised 1981.

Scale (Miles)



M&A Meredith & Associates, Inc.
 Scientific, Environmental Engineering, and Regulatory Consultants

DICO OIL COMPANY SITE
 1845 EAST WILLOW STREET
 SIGNAL HILL, CALIFORNIA

SITE LOCATION MAP

FIGURE

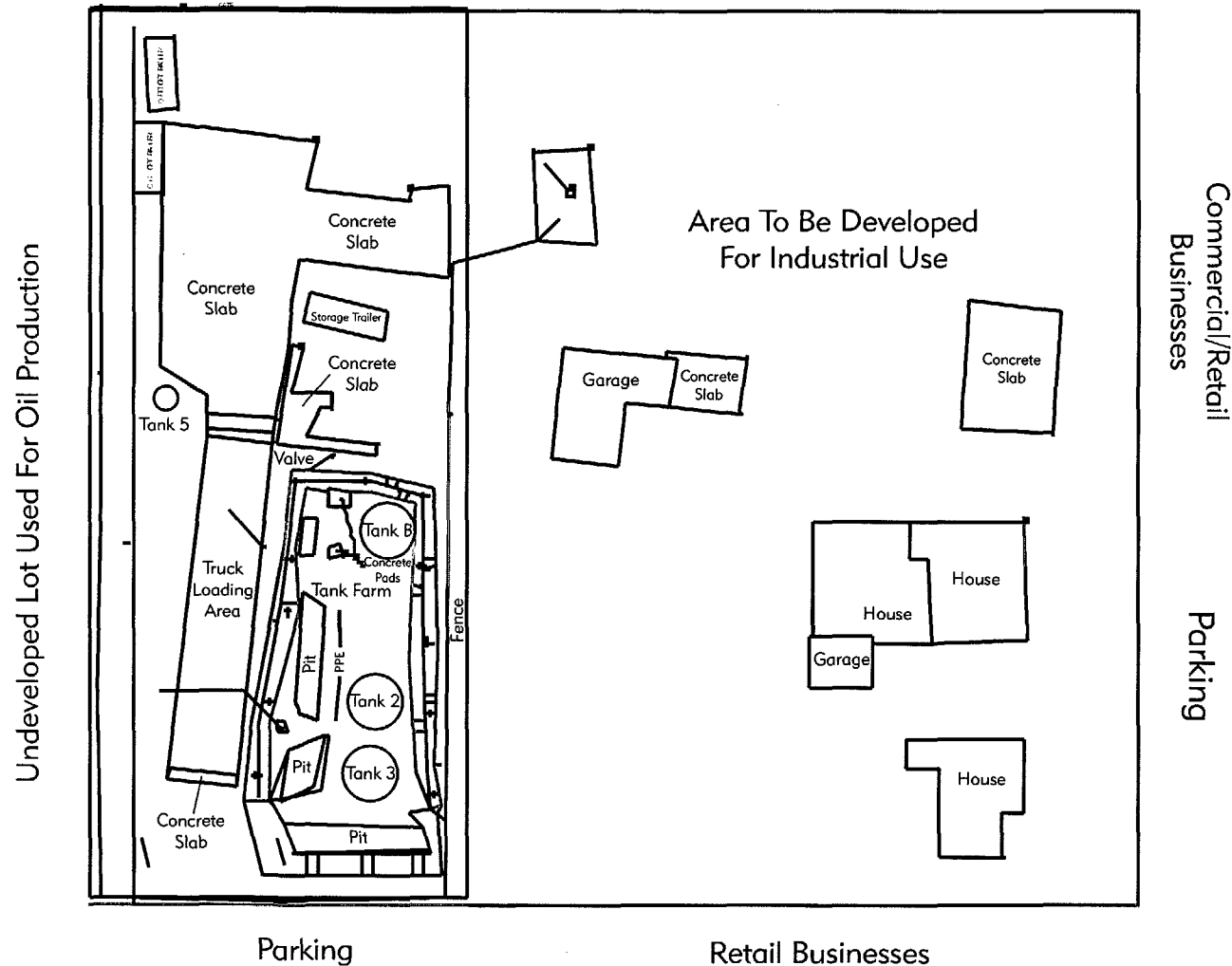
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12/09/03

Industrial Park

27TH STREET



0 30 60

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DICO OIL COMPANY SITE
1845 EAST WILLOW STREET
SIGNAL HILL, CALIFORNIA

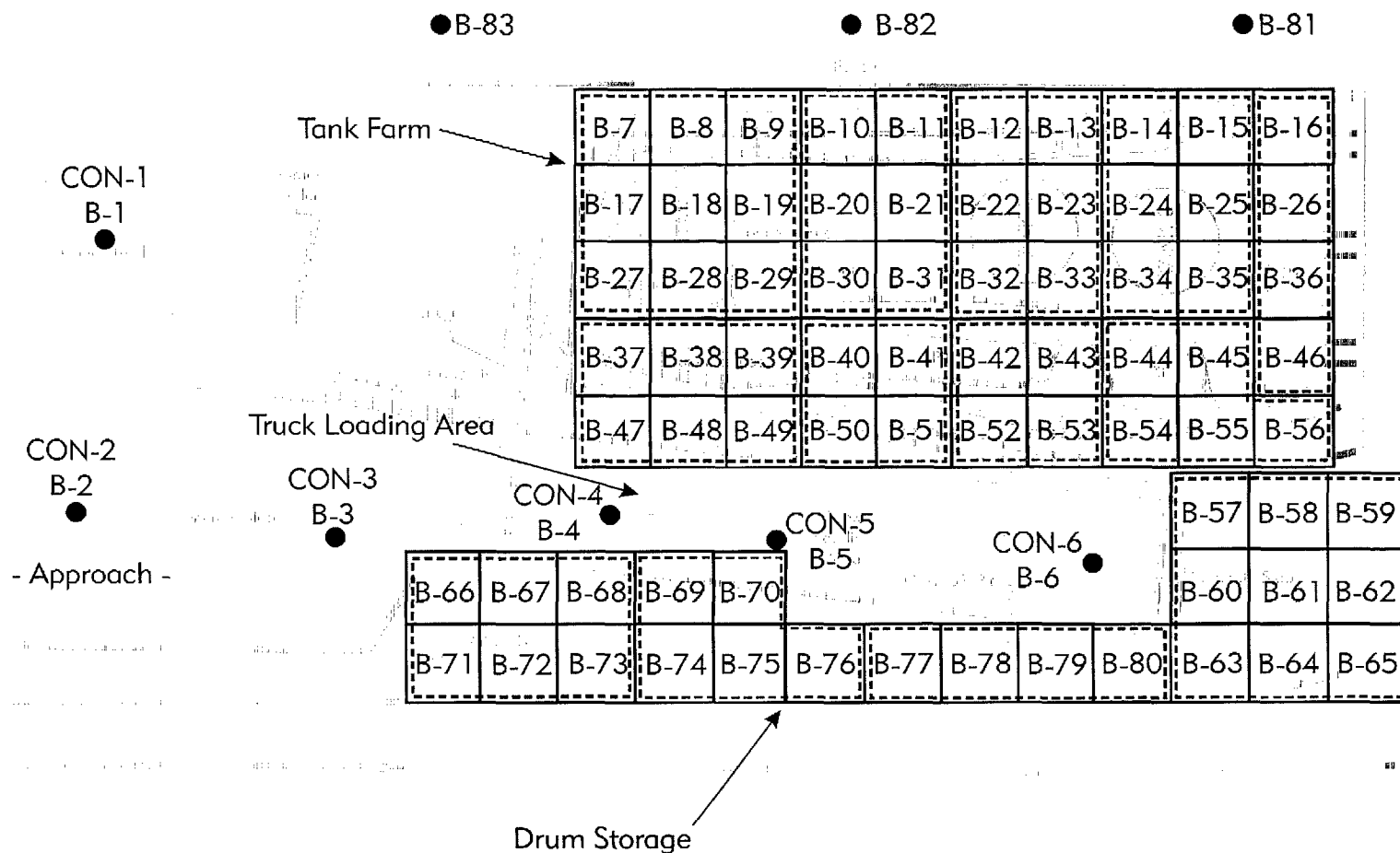
SITE PLAN AND ADJACENT LAND USE

FIGURE

2

2003-123

12/08/03



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DICO OIL COMPANY SITE
 1845 EAST WILLOW STREET
 SIGNAL HILL, CALIFORNIA

PROPOSED SAMPLE LOCATIONS

FIGURE 3

2003-123
 12/08/03

APPENDIX A
QUALITY ASSURANCE PROJECT PLAN (QAPP)

M&A Project No. MA-2003-123

QUALITY ASSURANCE PROJECT PLAN

Dico Oil Company Site
Signal Hill, California

Prepared by:

MEREDITH & ASSOCIATES, INC.
9841 Airport Boulevard, Suite 1010
Los Angeles, California 90045

November 26, 2003

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Appendix B	–	M&A Standard Operating Procedures – Sample Handling and Preservation

1.0 INTRODUCTION/BACKGROUND

This Quality Assurance Project Plan (QAPP) has been prepared by Meredith & Associates (M&A) to address quality assurance (QA) and quality control (QC) procedures associated with the collection of environmental data at the Dico Oil Company property (the "Site"). This QAPP presents the plan for sampling and analysis to be conducted in support of the investigation to be performed under the oversight of the United States Environmental Protection Agency (USEPA). USEPA policy requires a QAPP for all environmental data collection projects mandated or supported by the USEPA through regulations or other formalized means (USEPA, 1998a). The purpose of this QAPP is to identify the methods to be employed to establish technical accuracy, precision, and validity of data that are generated at the Site.

The sampling and analytical program is described in detail in the accompanying Workplan prepared for this Site. This QAPP contains general and specific details regarding field sampling, laboratory, and analytical procedures that apply to the planned field activities. It provides field and laboratory personnel with instructions regarding activities to be performed before, during, and after field sampling activities. These instructions will ensure that data collected for use in project decisions will be of the type and quality needed and expected for their intended purpose.

Guidelines followed in the preparation of this QAPP are described in EPA Requirements for Quality Assurance Plans for Environmental Data Operations (USEPA, 1998a) and EPA Guidance for Quality Assurance Project Plans (USEPA, 1998b). Other documents that are referenced in this plan include Guidance for the Data Quality Objectives Process (USEPA, 1994a) and Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (USEPA, SW-846, Third Edition, 1996).

2.0 PROJECT DESCRIPTION

The site was used by Dico Oil Company to blend used oil for sale to the fuel market. The Site is located at 1845 East Willow Street in Signal Hill, Los Angeles County, California. The site includes also properties identified as 2700 Rose Avenue and 2623 Gardenia Avenue.

The property was first developed in 1952, and Dico Oil used the property to operate an oil and recycling facility from 1960 to 1995. While in operation, Dico blended oils with varying amounts of water and sediment levels to create a marketable fuel. Asphalt emulsions, crude oil, diesel fuels, jet fuel, kerosene and Stoddard solvents, waste oils, and light to heavy fuel oils contaminated with water and solids were accepted from various sources and placed into six steel ASTs for processing and blending. The recycled oil then was sold primarily to the bunker oil market as ship fuel. Approximately two to three million gallons of oil were processed per year. Releases of waste oils to the environment have resulted in elevated levels of contaminants in Site soils. Chemicals of potential concern (COPCs), include the following:

- Total Petroleum Hydrocarbons in the Gasoline Range (TPH-g) -- USEPA Method 8015M/5035
- VOCs -- USEPA Method 8260B/5035
- Semi-Volatile Organic Compounds (SVOCs) -- USEPA Method 8270C
- CAM Metals (Lead and Chromium) -- USEPA Method 6010/7000
- Polychlorinated Biphenyls -- USEPA Method 8082.

The collection, analysis, and validation of environmental samples will be conducted in accordance with this QAPP, M&A's Standard Operating Procedures for Soil Sampling and Logging (Appendix A) and Sample Handling and Preservation (Appendix B).

3.0 DATA USE

It is intended that data collected through implementation of this QAPP will satisfy Federal, State, and local data quality requirements. The data will be used to characterize the nature and extent of impacted soil that may be present at the Site and to support decisions regarding possible further actions. The data must be of adequate quantity and quality to support the evaluation of Site conditions. Ultimately, the data must be adequate to support a "no further action" decision to allow Site closure activities to proceed.

4.0 PROJECT ORGANIZATION

This section provides a description of the organizational structure and responsibilities of the various individuals and entities associated with this project. This description is intended to define the lines of communication and identify key personnel and their responsibilities regarding various activities for the project. The organizational structure of the project is summarized in the following sections.

4.1 REGULATORY AGENCY

The USEPA Project Manager, will provide regulatory oversight for the project. The USEPA Project Manager's responsibilities will include the review and approval of workplans and work activities for the duration of the project. USEPA also will provide direction regarding agency policy and environmental objectives.

4.2 ECOLOGY AND THE ENVIRONMENT

Ecology and the Environment (ENE), as subcontractors to the USEPA, are responsible for day-to-day activities at the the Site. ENE is responsible for the directional decisions for work conducted at the Site. They may perform document review of related work plans, reports, and drawings for activities associated with this project.

4.3 MEREDITH & ASSOCIATES

The investigation contractor has responsibility for assigned phases of investigation and reporting. Together, the management team (Senior Project Manager, Senior Engineer, and Field Managers) will be responsible for the technical planning and implementation of the field investigation. The Quality Assurance (QA) staff has responsibility for effective planning, verification, and management of QA activities associated with the project.

Ms. Lynn Edlund is the M&A Project Manager. Ms Edlund will serve as the primary contact for M&A. Ms. Edlund has the authority to commit the necessary resources of M&A to ensure timely completion of project tasks. Her responsibilities include strategy development, budget control, document review, and will provide day-to-day management and tracking of the project schedule and budget. Other responsibilities include coordination and preparation of the required reports, and assignment of technical responsibilities to appropriate personnel or subcontractors.

Mr. Roger D. McCracken is the Field Manager and Site Safety Officer for M&A. Mr. McCracken is responsible for implementation of the field program. Mr. McCracken will be responsible for the day-to-day coordination of field activities. In addition, Mr. McCracken will assist with the sampling activities. Mr. McCracken also will fill

the role of QA Manager for soil samples to ensure that all required QA/QC protocols are met in the field and laboratory. Other responsibilities include coordination of subcontractors and field crews to ensure that field activities conform to the planned field investigation activities and the Health and Safety Plan.

4.4 LABORATORIES

A State-certified laboratory will provide laboratory handling and analysis for soil samples collected during the project. The laboratory will report to the Field Manager.

5.0 DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) have been identified for each data collection activity. All work will be conducted and documented so that the data collected are of sufficient quality for their intended use (USEPA, 1998a). DQOs specify the data type, quality, quantity, and uses needed to make decisions, and provide the basis for designing data collection activities. The DQOs have been used to help design the field investigation data collection activities. The DQOs for the project are described in the following sections.

5.1 DATA QUALITY OBJECTIVE PROCESS

The project DQOs developed specifically for the planned sampling and analysis program have been determined based on USEPA's seven-step DQO process (USEPA, 1994a). The Senior Engineer will evaluate the project DQOs to determine if the quantitative and qualitative needs of the sampling and analysis program have been met. The project definition associated with each step of the DQO process may be summarized as follows:

- State the Problem: The purpose of the sampling program is to complete the Site environmental characterization and update the human health hazard/risk evaluation. It includes the collection and analysis of soil vapor and soil matrix samples from designated locations. Although much of the Site will be covered with buildings or asphalt/concrete surfacing, exposed soils may exist in landscaped or recreational areas where future occupants could come into contact with the soil.
- Identify the Decision: The data obtained from the sampling and testing activities will be used to evaluate the nature, extent, and significance of impacted soil at specific Site locations. The data will be evaluated further to determine the need for the further investigation, analysis, and/or remedial action.
- Identify Inputs to the Decision: Inputs to the decision will include results of analytical testing of samples from selected locations on the Site. The specified analytes are discussed in Section 2.0.
- Define the Study Boundaries: The boundaries of the field sampling and analysis program are as described in the Workplan.
- Develop a Decision Rule: Decisions will be based upon laboratory results for the target constituents presented in Tables 1 and 2 for each respective matrix tested. If no valid detectable concentrations of target compounds are reported for the given samples, then a decision may be made that the Site is fully characterized with respect to the compounds tested and no further remedial action may be required. If target constituents are detected in the samples tested, then the data will be compiled for use in deciding what course of action to take with respect to this Site.
- Specify Limits on Decision Error: The results of the analytical testing will be subjected to data validation as specified in Section 8.3. Data are determined to be valid if the specified limits on precision, accuracy, representativeness, comparability, and completeness are achieved. The results of

any detected target constituents will be considered in evaluating the need for additional sampling of the soil matrix, and assessing the necessity for reducing any risks posed by the potential contamination.

- Optimize the Design: The field investigation has been designed to provide the type and quantity of data needed to satisfy each of the aforementioned objectives. The field investigation provides the specifications for the data collection activities, including the numbers of samples, respective locations and sampling techniques. The quality of the data will be assessed through the procedures further described in this QAPP.

5.2 PRECISION, ACCURACY, REPRESENTATIVENESS, COMPARABILITY, AND COMPLETENESS

The basis for assessing the elements of data quality is discussed in the following subsections. In the absence of laboratory-specific precision and accuracy limits, the QC limits listed in this section must be met.

5.2.1 Precision

Precision is the degree to which a measurement can be reproduced without assumption of any prior knowledge as to the true result. Precision is assessed by the means of duplicate/replicate sample analyses. The acceptability of replicate analyses is the evaluation of the relative percent difference (RPD) of control sample values. The RPD is calculated in all cases where matrix spike and matrix spike duplicate determination are made. Its definition is given below:

$$RPD = \frac{(X_1 - X_2)}{[(X_1 + X_2) / 2]} \times 100$$

Where X_1 and X_2 are measurements of the same parameter of duplicate/replicate sample analyses.

5.2.2 Accuracy

Accuracy is the determination of how close a measurement is to the actual value. It can be assessed by means of laboratory control samples (LCS), standard reference materials or spiked samples and their corresponding percent recoveries. The calculation of accuracy in terms of percent recovery is as follows:

$$\text{Percent Recovery} = \frac{(\text{Observed Value} - \text{Sample Value})}{\text{Known Value}} \times 100$$

The determination of the accuracy of a measurement requires knowledge of the known value for the parameter being measured.

5.2.3 Representativeness

Representativeness expresses the degree to which data accurately and precisely represents a characteristic of a given set of samples or data sets. The use of appropriate methods and sound judgement in the field will ensure that samples are representative. To maximize representativeness of results, sampling procedures should follow established protocols and sample locations should be chosen based on sound judgement and knowledge of the particular site. Some samples may require analysis of multiple phases to obtain representative results.

5.2.4 Completeness

Completeness is the amount of valid data obtained compared to the amount that was expected under ideal conditions. The number of valid results divided by the number of possible results, expressed as a percentage, determines the completeness of the data set. The objective for completeness is to recover at least 90 percent of the planned data to support field efforts. The formula for calculation of completeness is presented, as follows:

$$\% \text{ Completeness} = 100 \times \frac{\text{number of valid results}}{\text{number of expected results}}$$

5.2.5 Comparability

Comparability is an expression of confidence with which one data set can be compared to another. The objective of comparability is to ensure that data developed during the investigation are comparable to site knowledge and adequately address applicable criteria or standards established by the USEPA and California Department of Health Services (DHS). This QAPP addresses comparability by specifying laboratory methods that are consistent with the current standards of practice as approved by the USEPA and DHS.

6.0 QUALITY CONTROL ELEMENTS

This section presents QC requirements relevant to analysis of environmental samples that will be followed during all project analytical activities. The purpose of the QC program is to produce data of known quality that satisfy the project objectives and that meet or exceed the requirements of the standard methods of analysis. This program provides a mechanism for ongoing control and evaluation of data quality measurements through the use of QC materials.

6.1 QUALITY CONTROL PROCEDURES

The chemical data to be collected for this effort will be used to determine that the nature and extent of contamination, if any, at the Site is properly evaluated. As such, it is critical that the chemical data be of the highest confidence and quality. Consequently, strict QA/QC procedures will be adhered to. These procedures include:

- Adherence to strict protocols for field sampling and decontamination procedures
- Collection and laboratory analysis of appropriate field equipment and trip blanks to monitor for contamination of samples in the field or in the laboratory
- Collection and laboratory analysis of matrix spike, matrix spike duplicate, and field duplicate samples to evaluate precision and accuracy
- Attainment of completeness goals.

6.1.1 Equipment Decontamination

Non-dedicated equipment will be decontaminated before and after each sample is collected. The equipment will be washed in a non-phosphate detergent and potable water, rinsed in potable water, and then double rinsed in distilled water.

6.1.2 Standards

Standards used for calibration or to prepare samples will be certified by National Institute of Standards and Technology (NIST), USEPA, or other equivalent source. The standards will be current. The expiration date will be established by the manufacturer or based on chemical stability, the possibility of contamination, and environmental and storage conditions. Standards will be labeled with expiration dates, and will reference primary standard sources if applicable. Expired standards will be discarded.

6.1.3 Supplies

All supplies will be inspected prior to their use in the field or laboratory. The descriptions for sample collection and analysis contained in the methods will be used as a guideline for establishing the acceptance criteria for supplies. A current inventory and appropriate storage system for these materials will ensure their integrity prior to use. Efficiency and purity of supplies will be monitored through the use of standards and blank samples.

6.1.4 Holding Time Compliance

Sample preparation and analysis will be completed within the required method holding time (Table 1). Holding time begins at the time of sample collection. If holding times are exceeded, and the analyses are performed, the associated results will be qualified as described in the applicable validation procedure. The following definitions of extraction and analysis compliance are used to assess holding times:

- Preparation or extraction completion - completion of the sample preparation process as described in the applicable method, prior to any necessary extract cleanup.
- Analysis completion - completion of all analytical runs, including dilutions, second-column confirmations, and any required re-analysis.

6.1.5 Preventive Maintenance

The Field Manager and Project Geologist are responsible for documenting the maintenance of all field equipment prescribed in the manufacturer's specifications. Scheduled maintenance will be performed by trained personnel. The analytical laboratories are responsible for all analytical equipment calibration and maintenance as described in their laboratory QA Plan. Subcontractors are responsible for maintenance of all equipment needed to carry out subcontracted duties.

6.2 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) SAMPLES

The purpose of this QA/QC program is to produce data of known quality that satisfy the project objectives and that meet or exceed the requirements of the standard methods of analysis. This program provides a mechanism for ongoing control and evaluation of data quality measurements through the use of QC materials. QA/QC samples will be collected as part of the overall QA/QC program.

6.2.1 Laboratory Reagent Blanks

A laboratory reagent blank is de-ionized, distilled water that is extracted by the laboratory and analyzed as a sample. Analysis of the reagent blank indicates potential sources of contamination from laboratory procedures (e.g., contaminated reagents, improperly cleaned laboratory equipment, or persistent contamination due to presence of certain compounds in the ambient laboratory air).

6.2.2 Field Equipment Blanks

A field equipment blank is a sample that is prepared in the field by pouring de-ionized, distilled water into cleaned sampling equipment. The water is then collected and analyzed as a sample. Field equipment blanks are typically blind (given a fictitious name so that the laboratory will not recognize it as a blank). The field equipment blank gives an indication of contamination from field procedures (e.g., improperly cleaned sampling equipment, cross-contamination). The field equipment blanks should be analyzed using the same analyses requested for the associated primary samples collected.

6.2.3 Matrix Spike Samples

Matrix spikes are performed by the analytical laboratory to evaluate the efficiency of the sample extraction and analysis procedures, and are necessary because matrix interference (that is, interference from the sample matrix, in this case soil) may have a widely varying impact on the accuracy and precision of the extraction analysis. The matrix spike is prepared by the addition of known quantities of target compounds to a sample. The sample is extracted and analyzed. The results of the analysis are compared with the known additions and a matrix spike recovery is calculated giving an evaluation of the accuracy of the extraction and analysis procedures. Matrix spike recoveries are reviewed to check that they are within acceptable range. However, the acceptable ranges vary widely with both sample matrix and analytical method. Typically, matrix spikes are performed in duplicate in order to evaluate the precision of the procedures as well as the accuracy. Precision objectives (represented by agreement between matrix spike and matrix spike duplicate recoveries) and accuracy objectives (represented by matrix spike recovery results) are based on statistically generated limits established annually by the analytical laboratory. It is important to note that these objectives are to be viewed as goals, not as criteria. If matrix bias is suspected, the associated data will be qualified and the direction of the bias indicated in the data validation report.

6.2.4 Field Duplicate Samples

Field duplicate samples will be collected and analyzed to evaluate sampling and analytical precision. Field duplicates are collected and analyzed in the same manner as the primary samples. Agreement between duplicate sample results will indicate good sampling and analytical precision. Specific locations will be designated for collection of field duplicates prior to the start of field activities. The duplicate sample will be analyzed for all laboratory analyses requested for the primary sample collected. The precision goal for field duplicate analyses will be plus or minus 50 percent relative percent difference for aqueous samples and plus or minus 100 percent relative percent difference for soil matrix, or soil vapor samples.

6.2.5 Performance Evaluation Samples

Double blind performance evaluation (PE) samples may be submitted to the analytical laboratory during any site investigation. These samples may be of water or soil matrix, and are used to assess the accuracy of analytical procedures employed for a given sample set. If used, double blind PE samples will be prepared by Environmental Resources Standards, or similar supplier, in similar sample containers as the project field samples and shipped from the field to the laboratory for analysis.

Double blind PE samples will be prepared using NIST and/or A2LA certified standards. The project-specific PE samples will contain known concentrations of the analytes of interest. Laboratory results will be evaluated against the original Certificates of Analyses for precision and accuracy PE samples may be submitted for analysis as part of the laboratory pre-qualification process, or as part of a given sampling event. Results will be reported to the laboratory and presented with associated field sample results.

6.2.6 Soil Matrix QA/QC Samples

6.2.6.1 Soil Matrix Analytical Method Blank

Method blanks are analyzed to assess the level of background interference or contamination in the analytical system. A method blank is analyzed each time a batch is processed. When compounds are found in the blank, their values are evaluated to determine their effect on the analysis of environmental samples.

6.2.6.2 Soil Matrix Analytical Calibration Standard

Calibration check standards are analyzed to confirm that measurements were performed in an "in-control" mode of operation. The calibration check standard concentration is established near the midpoint of the calibration range. Instrument calibration is checked with every analytical batch. It is also verified once for at least every 15 measurements or at the end of a batch, whichever is more frequent. Calibration checks must be within 15% for all analytes of interest before proceeding with the analysis of samples.

6.2.6.3 Soil Matrix Analytical Lab Control Samples

Laboratory Control Samples (LCS) are prepared/obtained from sources independent of the calibration standards. The LCS concentration is established near the midpoint calibration range. An LCS must be prepared and analyzed once per batch of samples.

6.2.6.4 Soil Matrix Analytical Matrix Spikes

A matrix spike is an environmental sample into which known concentrations of analyte(s) have been added. The matrix spike sample is analyzed with environmental samples of the same matrix type in each batch and the results are used to evaluate sample matrix effects on method accuracy. For each method at least two compounds or 10 percent of the analytes of interest must be spiked.

6.2.6.5 Soil Matrix Analytical Matrix Spike Duplicates

A matrix spike duplicate is one of two QC checks of an environmental sample. It is spiked with the same concentration of an analyte(s) as the matrix spike. The matrix spike duplicate sample is analyzed with environmental samples of the same matrix type in each batch. The results evaluate sample matrix effects on method accuracy. Values obtained from the matrix spike and matrix spike duplicate analyses are compared to evaluate sample matrix effects on method precision.

6.2.6.6 Soil Matrix Analytical Surrogates

Surrogates are organic compounds which are similar to the analytes of interest, but are not normally found in environmental samples. Surrogates must be spiked into blanks, standards, spikes, and samples for organic analyses to monitor sample specific effects on method accuracy. They should not interfere with target analytes.

6.2.6.7 Soil Matrix Trip/Field Blank

Trip blanks accompany the sample containers during transport, collection, and storage. Field blanks are analogous to trip blanks, except field blanks are opened at the site during sampling activities.

6.2.6.8 Soil Matrix Field Equipment (Rinseate) Blank

Aqueous samples that are collected by pouring deionized water over freshly decontaminated soil sampling equipment.

6.2.6.9 Soil Matrix Field Duplicate (Collocated)

Soil samples that are collected from the same location as the primary soil sample. The primary sample and its duplicate are analyzed as separate samples to assess precision.

7.0 SAMPLING PROCEDURES

The defensibility of data is dependent on the use of well defined, accepted sampling procedures. This section describes the sampling and handling procedures that will be followed for each sampling event.

7.1 FIELD PROCEDURES

Collection of environmental samples of high integrity is important to the quality of chemical data to be generated. To this end, strict field procedures have been developed and will be employed during the field investigation. These procedures are described in Appendixes A and B hereto.

7.2 SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIMES

Table 1 lists the required sample containers, preservatives, and recommended maximum holding times for soil matrix samples. Sample containers provided by the laboratory will be purchased commercially from I-Chem, Eagle Pitcher, or other equivalent source.

7.3 SAMPLE HOLDING AND STORAGE

In the field, each soil matrix sample container will be marked with the sampling location number, and date and time of sample collection. All soil matrix sample containers will be wiped with paper towels and securely packed, in a cooler on ice, in preparation for delivery to the laboratory.

Upon receipt of the samples, the laboratory will immediately notify the Field Manager or the Project Geologist if conditions or problems are identified which require immediate resolution. Such conditions include, container breakage, missing or improper chain-of-custody, exceeded holding times, missing or illegible sample labeling, or temperature excursions.

7.4 SAMPLE CUSTODY

For each sample that is submitted to the laboratory for analysis, an entry will be made on a chain-of-custody form supplied by the laboratory. The information to be recorded includes the sampling date and time, sample identification number, matrix type, requested analyses and methods, preservatives, and the sampler's name. Sampling team members will maintain custody of the samples until they are relinquished to laboratory personnel or a professional courier service. The chain-of-custody form will accompany the samples from the time of collection until received by the laboratory. Each party in possession of the samples (except the professional courier service) will sign the chain-of-custody form signifying receipt. The chain-of-custody form will be placed in a plastic bag and shipped with samples inside the cooler. After the samples, ice, and chain-of-custody forms are packed in the coolers, the cooler will be appropriately sealed before it is relinquished to the courier. A copy of the

original completed form will be provided by the laboratory along with the report of results. Upon receipt, the laboratory will inspect the condition of the sample containers and report the information on chain-of-custody or similar form.

8.0 ANALYTICAL PROCEDURES

The analytical methods used for this project are primarily USEPA approved methods and are listed in Table 1 hereto. Specific analytical method procedures are detailed in the laboratory QA Plan and standard operating procedures of the selected laboratories. These documents may be reviewed by M&A quality assurance staff during laboratory audits to ensure that project specifications are met. Laboratory audits are discussed in Section 9.2.

8.1 INTERNAL STANDARDS

Internal standards are measured amounts of method-specified compounds added after preparation, or extraction, of a sample. Internal standards are added to samples, controls, and blanks in accordance with method requirements to identify column injection losses, purging losses, or viscosity effects.

Acceptance limits for internal standard recoveries are set forth in the applicable method. If the internal standard recovery falls outside of acceptance criteria, the instrument will be checked for malfunction and reanalysis of the sample will be performed after any problems are resolved.

8.2 RETENTION TIME WINDOWS

Retention time windows will be established as described in SW-846 Method 8000A for applicable analyses of organic compounds. Retention time windows are used for qualitative identification of analytes and are calculated based on multiple, replicated analyses of a respective standard.

Retention times will be checked on a daily basis. Acceptance criteria for retention time windows are established in the referenced method. If the retention time falls outside the respective window, actions will be taken to correct the problem. The instrument must be re-calibrated after any retention time window failure and the affected samples must be reanalyzed.

8.3 METHOD DETECTION LIMITS

The method detection limit (MDL) is the minimum concentration of an analyte, or compound, that can be measured and reported with 99 percent confidence that the concentration is greater than zero. MDLs are established for each method, matrix and analyte, and for each instrument used to analyze project samples. MDLs are derived using the procedures described in 40 CFR 136 Appendix B (USEPA, 1990). USEPA requires that MDLs be established on an annual basis. MDLs must be less than applicable reporting limits for each target analyte presented in Tables 2 and 3 hereto. For selected analytes, the laboratory may report detected concentrations that are above the MDL but below the laboratory's typical reporting limit. These data will be "j" flagged and evaluated closely since detections near the MDL can have high variability.

8.4 INSTRUMENT CALIBRATION

Analytical instruments will be calibrated in accordance with the procedures specified in the applicable method. All analytes that are reported shall be present in the initial and continuing calibrations, and these calibrations must meet the acceptance criteria specified in the reference method. Records of standard preparation and instrument

calibration will be maintained. Records shall unambiguously trace the preparation of standards and their use in calibration and quantitation of sample results. Calibration records will be traceable to standard materials as described in Section 6.1.2.

At the onset of analysis, instrument calibration will be checked using all of the analytes of interest. At a minimum, calibration criteria will satisfy method requirements. Analyte concentrations can be determined with either calibration curves or response factors, as defined in the method. Guidance provided in SW-846 should be considered to determine appropriate evaluation procedures.

9.0 DATA REPORTING

This section presents reporting requirements relevant to the data produced during all project analytical activities.

9.1 FIELD DATA

Data measured by field instruments will be records in field notebooks, laptops, and/or on required field forms. Examples of field documentation forms are included in Appendix B hereto. Units of measure for field analyses are identified on the field forms. The field data will be reviewed by the Senior Engineer, Field Manager, and Project Geologist to evaluate completeness of the field records and appropriateness of the field methods employed. All field records will be retained in the project files.

9.2 LABORATORY DATA

Analytical data will contain the necessary sample results and quality control data to evaluate the DQOs defined for the project. Documentation requirements for laboratory data are defined in USEPA Region 9 Draft Laboratory Documentation Requirements for Data Validation (USEPA, 1997). The laboratory reports from the fixed laboratory will be consistent with USEPA Level II documentation and include the following data and summary forms:

- Narrative, cross-reference, chain-of-custody, and method references
- Analytical results
- Surrogate recoveries (as applicable)
- Calibration summary
- Blank results
- Laboratory control sample recoveries
- Duplicate sample results or duplicate spike recoveries
- Sample spike recoveries
- Instrument tuning summary
- Associated raw data
- Magnetic tape or equivalent upon request.

Data validation criteria are derived from the USEPA Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review (USEPA, 1994b and 1994c). The National Functional Guidelines provide specific data validation criteria that can be applied to data generated for this investigation.

The laboratory data will be reviewed for compliance with the applicable method and the quality of the data reported. The following summarizes the areas of data validation.

- Data Completeness
- Holding Times
- Calibrations
- Blanks
- Laboratory Control Samples
- Matrix Spike/Matrix Spike Duplicates
- Surrogates/Internal Standards (as applicable)
- Field Quality Control Samples
- Compound Identification and Quantification.

The application of data validation criteria is a function of project-specific DQOs. The Senior Scientist will determine if the data quality objectives for the analytical data have been met. Results of the data validation review will be documented and summarized in the final Removal Action Report.

9.3 PROCEDURES FOR DATA VALIDATION

Guidance for performing data validation for the types of analyses to be utilized for this investigation is provided in the National Functional Guidelines. Data validation will be documented in a manner consistent with these functional guidelines. The results of the data validation will be included in the final Removal Action Report. This documentation will be maintained in the project files.

9.4 DATA QUALIFIERS

The data validation procedures were designed to review each data set and identify biases inherent to the data and determine its usefulness. Data validation flags are applied to those sample results that fall outside of specified tolerance limits, and, therefore, did not meet the program's quality assurance objectives described in Section 5.0. Data validation flags to be used for this project are defined in the National Functional Guidelines. Data validation flags will indicate if results are considered anomalous, estimated, or rejected. Only rejected data are considered unusable for decision-making purposes; however, other qualified data may require further verification.

10.0 PERFORMANCE AND SYSTEM AUDITS

Audit programs are established and directed by the M&A and laboratory staff to ensure that field and laboratory activities are performed in compliance with project controlling documents. This section describes responsibilities, requirements and methods for scheduling, conducting and documenting audits of field and laboratory activities.

10.1 FIELD AUDITS

Field audits focus on appropriateness of personnel assignments and expertise, availability of field equipment, adherence to project controlling documents for sample collection and identification, sample handling and transport, use of QA samples, chain-of-custody procedures, equipment decontamination and documentation. Field audits are not required, but may be performed in the event significant discrepancies are identified that warrant evaluation of field practices.

10.2 LABORATORY AUDITS

Laboratory audits include reviews of sample handling procedures, internal sample tracking, SOPs, analytical data documentation, QA/QC protocols, and data reporting. Any selected mobile or offsite laboratory will be licensed by the State of California as a certified testing laboratory, and will participate in a DHS approved Performance Evaluation Program for hazardous waste and wastewater analyses. If no previous audit has been conducted by M&A, a scheduled audit will be conducted by the quality assurance staff during the course of this project to ensure the integrity of sample handling and processing by the laboratory.

10.3 DATA AUDITS

Data audits will be performed on analytical results received from the laboratories. These audits will be accomplished through the process of data validation as described in Section 9.3, or may involve a more detailed review of laboratory analytical records. Data audits require the laboratory to submit complete raw data files to M&A for validation and verification. M&A staff will perform a review of the data consistent with the level of effort described in the National Functional Guidelines. This level of validation consists of a detailed review of sample data, including verification of data calculations for calibration and quality control samples to assess if these data are consistent with method requirements. Upon request, the laboratory will make available all supporting documentation in a timely fashion.

10.4 SCHEDULING

Audits will be scheduled such that field and laboratory activities are adequately monitored, or in the event discrepancies are identified. The overall frequency of audits conducted for these activities will be based on the importance and duration of work, as well as significant changes in project scope or personnel.

10.5 REPORTS TO MANAGEMENT AND RESPONSIBILITIES

Upon completion of any audit, the auditor will submit to the Senior Scientist and Field Manager a report or memorandum describing any problems or deficiencies identified during the audit. It is the responsibility of the Project Manager to determine if the deviations will result in any adverse effect on the project conclusions. If it is determined that corrective action is necessary, procedures outlined in Section 10.6 will be followed.

10.6 CORRECTIVE ACTION

Corrective actions will be initiated whenever data quality indicators suggest that DQOs have not been met. Corrective actions will begin with identifying the source of the problem. Potential problem sources include failure to adhere to method procedures, improper data reduction, equipment malfunctions, or systemic contamination. The first level of responsibility for identifying the problems and initiating corrective action lies with the analyst/field personnel. The second level of responsibility lies with any person reviewing the data. Corrective actions may include more intensive staff training, equipment repair followed by a more intensive preventive maintenance program, or removal of the source of systemic contamination. Once resolved, the corrective action

procedure will be fully documented, and if DQOs were not met, the samples in question must be recollected and/or reanalyzed utilizing a properly functioning system.

11.0 REFERENCES

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TABLES

TABLE 1

SUMMARY OF ANALYSES - SOIL MATRIX

Dico Oil Company Site
Signal Hill, California

SOIL MATRIX ANALYSES				
Analyte	Method	Container	Preservative	Holding Time
Semi-Volatile Organic Compounds	USEPA 8270C	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	14 days to extraction, 40 days to analysis
CAM Metals (see Table 2)	USEPA 6010/7000	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	180 days mercury: 30 days
Volatile Organic Compounds	USEPA 8260B/5035	metal sleeves; subsamples to glass VOAs	Sodium Bisulfate; Methanol; Freeze -10 °C	sodium bisulfate: 48 hours methanol: 14 days frozen samples: 7 days
TPH (extended)	USEPA 8015M	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	14 days to extraction, 40 days to analysis
Polychlorinated Biphenyls	USEPA 8082	4 oz glass or metal sleeve	Temperature: Cool, 4 °C	14 days to extraction, 40 days to analysis

TABLE 2

**LIST OF METHOD DETECTION AND REPORTING LIMITS
SOIL MATRIX ANALYSES**

**Dico Oil Company Site
Signal Hill, California**

Chemical Constituent	Unit	MDL ⁽¹⁾	PQL ⁽²⁾
TPH (M8015D)			
TPH as Diesel	mg/kg	5	10
TPH as Heavy Hydrocarbon	mg/kg	5	10
TPH Total as Diesel and Heavy Hydrocarbons	mg/kg	5	10
TPH as Gasoline	mg/kg	0.5	1
VOCs (8260B)			
Acetone	ug/kg	25	50
Benzene	ug/kg	2	10
Bromobenzene (Phenyl bromide)	ug/kg	5	10
Bromochloromethane	ug/kg	5	10
Bromodichloromethane	ug/kg	5	10
Bromoform (Tribromomethane)	ug/kg	25	50
Bromomethane (Methyl bromide)	ug/kg	15	30
2-Butanone (MEK)	ug/kg	25	50
n-Butylbenzene	ug/kg	5	10
sec-Butylbenzene	ug/kg	5	10
tert-Butylbenzene	ug/kg	5	10
Carbon Disulfide	ug/kg	25	50
Carbon Tetrachloride	ug/kg	5	10
Chlorobenzene	ug/kg	5	10
Chloroethane	ug/kg	15	30
2-Chloroethyl vinyl ether	ug/kg	50	50
Chloroform (Trichloromethane)	ug/kg	5	10
Chloromethane (Methyl chloride)	ug/kg	15	30
2-Chlorotoluene	ug/kg	5	10
4-Chlorotoluene	ug/kg	5	10
1,2-Dibromo-3-chloropropane (DBCP)	ug/kg	25	50
Dibromochloromethane	ug/kg	5	10
1,2-Dibromoethane (EDB)	ug/kg	5	10
Dibromomethane	ug/kg	5	10
1,2-Dichlorobenzene	ug/kg	5	10
1,3-Dichlorobenzene	ug/kg	5	10
1,4-Dichlorobenzene	ug/kg	5	10
Dichlorodifluoromethane	ug/kg	15	30
1,1-Dichloroethane	ug/kg	5	10
1,2-Dichloroethane (EDC)	ug/kg	5	10
1,1-Dichloroethene	ug/kg	5	10
cis-1,2-Dichloroethene	ug/kg	5	10
trans-1,2-Dichloroethene	ug/kg	5	10
1,2-Dichloropropane	ug/kg	5	10
1,3-Dichloropropane	ug/kg	5	10
2,2-Dichloropropane	ug/kg	5	10
1,1-Dichloropropene	ug/kg	5	10
cis-1,3-Dichloropropene	ug/kg	5	10
trans-1,3-Dichloropropene	ug/kg	5	10
Ethylbenzene	ug/kg	2	10

TABLE 2

**LIST OF METHOD DETECTION AND REPORTING LIMITS
SOIL MATRIX ANALYSES**

**Dico Oil Company Site
Signal Hill, California
(continued)**

Chemical Constituent	Unit	MDL ⁽¹⁾	PQL ⁽²⁾
VOCs (8260B; concluded)			
Hexachlorobutadiene	ug/kg	15	30
2-Hexanone	ug/kg	25	50
Isopropylbenzene	ug/kg	5	10
p-Isopropyltoluene	ug/kg	5	10
4-Methyl-2-pentanone (MIBK)	ug/kg	25	50
Methyl-tert-butyl ether (MTBE)	ug/kg	5	10
Methylene chloride (DCM)	ug/kg	5	50
Naphthalene	ug/kg	5	10
n-Propylbenzene	ug/kg	5	10
Styrene	ug/kg	5	10
1,1,1,2-Tetrachloroethane	ug/kg	5	10
1,1,2,2-Tetrachloroethane	ug/kg	5	10
Tetrachloroethene	ug/kg	5	10
Toluene (Methyl benzene)	ug/kg	5	10
1,2,3-Trichlorobenzene	ug/kg	5	10
1,2,4-Trichlorobenzene	ug/kg	5	10
1,1,1-Trichloroethane	ug/kg	5	10
1,1,2-Trichloroethane	ug/kg	5	10
Trichloroethene	ug/kg	5	10
Trichlorofluoromethane	ug/kg	5	10
1,2,3-Trichloropropane	ug/kg	5	10
1,2,4-Trimethylbenzene	ug/kg	5	10
1,3,5-Trimethylbenzene	ug/kg	5	10
Vinyl Acetate	ug/kg	25	50
Vinyl chloride (Chloroethene)	ug/kg	15	30
o-Xylene	ug/kg	2	10
m,p-Xylenes	ug/kg	2	20
SVOCs (8270C)			
Acenaphthene	mg/kg	0.25	0.50
Acenaphthylene	mg/kg	0.25	0.50
Anthracene	mg/kg	0.25	0.50
Benzo(a)anthracene	mg/kg	0.25	0.50
Benzo(a)pyrene	mg/kg	0.25	0.50
Benzo(b)fluoranthene	mg/kg	0.25	0.50
Benzo(ghi)perylene	mg/kg	0.25	0.50
Benzo(k)fluoranthene	mg/kg	0.25	0.50
Benzoic Acid	mg/kg	0.25	0.50
Benzyl Alcohol	mg/kg	0.25	0.50
Bis(2-Chloroethoxy)methane	mg/kg	0.25	0.50
Bis(2-Chloroethyl)ether	mg/kg	0.25	0.50
Bis(2-chloroisopropyl)ether	mg/kg	0.25	0.50
Bis(2-ethylhexyl)phthalate	mg/kg	0.25	0.50
4-Bromophenyl phenyl ether	mg/kg	0.25	0.50
Butyl benzyl phthalate	mg/kg	0.25	0.50

TABLE 2

**LIST OF METHOD DETECTION AND REPORTING LIMITS
SOIL MATRIX ANALYSES**

**Dico Oil Company Site
Signal Hill, California
(continued)**

Chemical Constituent	Unit	MDL ⁽¹⁾	PQL ⁽²⁾
SVOCs (8270C; continued)			
4-Chloro-3-methylphenol	mg/kg	0.25	0.50
4-Chloroaniline	mg/kg	0.25	0.50
2-Chloronaphthalene	mg/kg	0.25	0.50
2-Chlorophenol	mg/kg	0.25	0.50
4-Chlorophenyl phenyl ether	mg/kg	0.25	0.50
Chrysene	mg/kg	0.25	0.50
Di-n-butyl phthalate	mg/kg	0.25	0.50
Di-n-octyl phthalate (Diocetyl ester)	mg/kg	0.25	0.50
Dibenzo(a,h)anthracene	mg/kg	0.25	0.50
Dibenzofuran	mg/kg	0.25	0.50
1,2-Dichlorobenzene	mg/kg	0.25	0.50
1,3-Dichlorobenzene	mg/kg	0.25	0.50
1,4-Dichlorobenzene	mg/kg	0.25	0.50
3,3-Dichlorobenzidine	mg/kg	0.25	0.50
2,4-Dichlorophenol	mg/kg	0.25	0.50
Diethyl phthalate (Diethyl ester)	mg/kg	0.25	0.50
Dimethyl phthalate (Dimethyl ester)	mg/kg	0.25	0.50
2,4-Dimethylphenol	mg/kg	0.25	0.50
4,6-Dinitro-2-methylphenol	mg/kg	0.25	0.50
2,4-Dinitrophenol	mg/kg	0.25	0.50
2,4-Dinitrotoluene	mg/kg	0.25	0.50
2,6-Dinitrotoluene (2,6-DNT)	mg/kg	0.25	0.50
Fluoranthene	mg/kg	0.25	0.50
Fluorene	mg/kg	0.25	0.50
Hexachlorobenzene	mg/kg	0.25	0.50
Hexachlorobutadiene	mg/kg	0.25	0.50
Hexachloroethane	mg/kg	0.25	0.50
Indeno(1,2,3-cd)pyrene	mg/kg	0.25	0.50
Isophorone	mg/kg	0.25	0.50
2-Methylnaphthalene	mg/kg	0.25	0.50
4-Methylphenol	mg/kg	0.25	0.50
2-Methylphenol (2-Cresol)	mg/kg	0.25	0.50
3-Methylphenol (3-Cresol)	mg/kg	0.25	0.50
N-Nitroso-Di-n-propylamine	mg/kg	0.25	0.50
Naphthalene	mg/kg	0.25	0.50
2-Nitroaniline	mg/kg	0.25	0.50
3-Nitroaniline	mg/kg	0.25	0.50
4-Nitroaniline	mg/kg	0.25	0.50
Nitrobenzene (NB)	mg/kg	0.25	0.50
4-Nitrophenol	mg/kg	0.25	0.50
2-Nitrophenol (o-nitrophenol)	mg/kg	0.25	0.50
N-nitrosodiphenylamine	mg/kg	0.25	0.50
Pentachlorophenol	mg/kg	0.25	0.50
Phenanthrene	mg/kg	0.25	0.50

TABLE 2

**LIST OF METHOD DETECTION AND REPORTING LIMITS
SOIL MATRIX ANALYSES**

**Dico Oil Company Site
Signal Hill, California
(concluded)**

Chemical Constituent	Unit	MDL ⁽¹⁾	PQL ⁽²⁾
SVOCs (8270C; concluded)			
Phenol	mg/kg	0.25	0.50
Pyrene	mg/kg	0.25	0.50
1,2,4-Trichlorobenzene	mg/kg	0.25	0.50
2,4,5-Trichlorophenol	mg/kg	0.25	0.50
2,4,6-Trichlorophenol	mg/kg	0.25	0.50
CAM Metals (6010/7000)			
Antimony	mg/kg	0.5	1
Arsenic	mg/kg	0.3	0.3
Barium	mg/kg	2.5	5
Beryllium	mg/kg	0.1	0.2
Cadmium	mg/kg	0.1	0.2
Chromium	mg/kg	2.5	5
Cobalt	mg/kg	2.5	5
Copper	mg/kg	2.5	5
Lead	mg/kg	2.5	5
Mercury (By EPA 7471)	mg/kg	0.1	0.2
Molybdenum	mg/kg	2.5	5
Nickel	mg/kg	2.5	5
Selenium	mg/kg	0.5	1
Silver	mg/kg	2.5	5
Thallium	mg/kg	0.3	0.5
Vanadium	mg/kg	2.5	5
Zinc	mg/kg	2.5	5
PCBs (8082)			
Aroclor-1016 (PCB-1016)	ug/kg	35	35
Aroclor-1221 (PCB-1221)	ug/kg	70	70
Aroclor-1232 (PCB-1232)	ug/kg	35	35
Aroclor-1242 (PCB-1242)	ug/kg	35	35
Aroclor-1248 (PCB-1248)	ug/kg	35	35
Aroclor-1254 (PCB-1254)	ug/kg	35	35
Aroclor-1260 (PCB-1260)	ug/kg	35	35
Aroclor-1262 (PCB-1262)	ug/kg	35	35
Aroclor-1268 (PCB-1268)	ug/kg	35	35

⁽¹⁾ MDL = Method Detection Limit

⁽²⁾ PQL = Practical Quantitation (Reporting) Limit

APPENDIX A

**M&A STANDARD OPERATING PROCEDURES –
SOIL SAMPLING AND LOGGING**

M/B&A STANDARD OPERATING PROCEDURES

SOIL SAMPLING AND LOGGING

**M/B&A STANDARD OPERATING PROCEDURES
SOIL SAMPLING AND LOGGING**

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Attachment B -- M/B&A Boring Log

1.0 INTRODUCTION

The collection and logging (i.e., description) of soil samples is a vital component of many environmental site assessments and remedial investigations. The ability to define the geologic and hydrogeologic setting at a site depends heavily on data derived from soil samples. Furthermore, chemical analysis of soil samples often is critical in defining the nature and extent of contamination. In most instances, soil sampling objectives will include collection of samples that 1) are representative of existing subsurface conditions and 2) are valid for chemical analysis. To the maximum extent possible, soil samples should not be cross-contaminated, physically disturbed, or chemically altered during the sampling process.

This standard operating procedure (SOP) describes soil sampling methods widely used in remedial investigations and other environmental projects. The SOP also presents a consistent method for describing and identifying soil samples in the field. The objectives of this SOP are outlined below:

- Facilitate selection of a soil sampling method that is appropriate for site-specific conditions and project objectives
- Ensure consistent and accurate soil description and classification
- Attain project chemical data quality objectives (DQOs)

The SOP is intended for use by M/B&A geologists, engineers, and project managers during project planning and implementation. It focuses on methods and equipment that are readily available and are typically applied. It is not intended to provide an all-inclusive discussion of soil sampling methods. Sample types, samplers, and soil logging standards and procedures are discussed in the following sections.

2.0 DEFINITIONS

Bulk Samples

Soil samples typically collected from soil stockpiles or drummed soil wastes using a trowel or shovel. The exact source of the bulk soil samples (i.e., boring location and depth) is not known with certainty.

Composite Samples

Blended or mixed soil samples used to represent "average" properties or chemical concentrations for a selected part of the site or over a defined depth range in a boring.

Field Blanks

Field blanks are analogous to trip blanks (see definition below), except that the field blanks are opened at the site during the sampling activities.

Field Duplicate Samples

Soil samples that are collected from the same location as the primary soil sample. The primary sample and its duplicate are analyzed as separate samples using the same analytical method(s) to assess project precision.

QA Split (Laboratory) Samples

Soil samples similar to field duplicate samples, but analyzed by a different laboratory than the primary samples.

Representative Samples

Soil samples that reflect in-situ, subsurface conditions; commonly collected with a split-barrel sampler or a push-type sampling tube.

Rinsate (Equipment) Blanks

Aqueous samples that are collected by pouring deionized water over freshly decontaminated soil sampling equipment, such as a split-barrel sampler. Rinsate blanks are used to evaluate the effectiveness of decontamination procedures.

Solid-Barrel Samplers

Cylindrical metal samplers that commonly are equipped with sample liners or sleeves. Solid-barrel samplers typically range from 1 to 6 inches in diameter and are constructed of steel or stainless steel.

Split-Barrel Samplers

Cylindrical metal samplers (also referred to as split-spoon samplers) that are split longitudinally into two halves and often are equipped with sample sleeves. Samples typically are collected by driving the sampler with a 140-pound drop hammer as specified in ASTM Standard D 1586-84.

Thin-Walled (Shelby) Tube Samplers

Consist of 30- to 36-inch long steel or stainless steel tubes that are pushed into the formation to collect an undisturbed soil sample.

Trip Blanks

Soil samples that typically are composed of an uncontaminated reference soil standard. Trip blanks accompany the sample containers during transport, collection, and storage and are used to assess widespread environmental contaminants.

3.0 SOIL SAMPLING

3.1 CATEGORIES OF SAMPLES

Four general categories of soil samples are collected during site investigations: bulk samples, representative samples, undisturbed samples, and composite samples. These categories are described in the following subsections.

3.1.1 Bulk Samples

Bulk soil samples generally consist of a shovelful or trowelful of material collected from stockpiled or drummed soil cuttings. There may be uncertainty over the exact depth and/or location that the bulk soil sample represents. This type of sampling is used less frequently during environmental investigations and is the least accurate of the four basic sample types. Bulk soil sampling typically is used for waste characterization/profiling purposes.

3.1.2 Representative Samples

“Representative” soil samples are in-situ, subsurface soil samples that are collected with a drive sampler or push-type sampling tube. Although representative samples may be physically disturbed to a degree, they generally reflect all of the sediment and chemical constituents that are present at a given depth interval. Representative soil samples are the most common type of soil sample in environmental investigations.

3.1.3 Undisturbed Samples

“Undisturbed” soil samples are samples collected under strictly controlled conditions so as to minimize structural disturbance. Undisturbed samples typically are collected where in-situ, subsurface structural or geometric relationships need to be preserved. Undisturbed samples generally are required for geotechnical or structural geologic investigations and are used less frequently for environmental assessments.

3.1.4 Composite Samples

Composite soil samples represent a blend or mix of sample material that may reflect two or more sample locations or stratigraphic intervals. Composite samples can be used to represent “average” properties for a selected part of the site or for the entire vertical extent of a particular boring. Homogenized soil samples are a form of composite samples that are derived from a specified depth interval. For example, if a homogenized sample reportedly represented the 10.0- to 11.5-foot depth interval, the material from that interval would have been blended mechanically (i.e., homogenized) before being placed in an appropriate sample container. Due

to concerns over volatile loss, samples intended for volatile organic compound (VOC) or semi-volatile organic compound (SVOC) analysis are not to be composited or homogenized.

3.2 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) SAMPLES

Samples also are collected and analyzed with the specific goals of assessing data quality and evaluating the effectiveness of field protocols, such as sampling procedures and decontamination protocols. These samples generally are referred to as QA/QC samples; they may consist of any one of the four general categories of samples discussed in preceding Section 3.1. QA and QC can be viewed respectively as 1) "a set of operating principles that, if strictly followed during sample collection and analysis, will produce data of known and defensible quality" and 2) "procedures or activities undertaken to ensure that the data meet appropriate standards" (Wilson, 1995). Adherence to approved sampling methods, as discussed in this SOP, and identification of QA/QC sampling needs during the planning stages of a project, are vital in the aforementioned process. Following is a brief discussion of several different types of QA/QC samples that are employed during soil sampling programs.

- Field duplicate samples - Soil samples that are collected from the same sample location as the primary soil sample. Field duplicate soil samples often consist of adjacent sample sleeves within a split-barrel sampler; such samples may be referred to as "co-located" samples. The field sample and its duplicate are analyzed as separate samples using the same analytical method(s); the results of these analyses are used to assess project precision. Duplicate samples generally are assigned fictitious sample numbers on the chain-of-custody record to shield their identity. Most agency guidelines prescribe a duplicate sample frequency of at least one in ten samples (i.e., 10%)
- Rinsate (equipment) blanks - Aqueous samples that are collected by pouring deionized water over freshly decontaminated soil sampling equipment, such as a split-barrel sampler. The laboratory analysis of rinsate blanks helps assess the effectiveness of equipment decontamination procedures. Agency guidelines for rinsate blank collection vary; collection of at least one rinsate blank per day of soil sampling commonly is recommended (Wilson, 1995)
- QA split (laboratory) samples - A soil sample similar to a field duplicate sample but analyzed by a different laboratory than the primary field sample. Split samples may be collected and relinquished to regulatory personnel, private- or Federal-sector client representatives, or third-parties (attorneys, other consultants, etc.) and are used to evaluate laboratory precision. The need for, and frequency of QA split samples should be evaluated on a project-by-project basis
- Trip blank - A soil sample that typically consists of a glass sample container that has been filled with a reference soil standard at the laboratory *prior to* sampling activities. The trip blank accompanies

the sample containers during transport, collection, and storage and is analyzed to assess widespread environmental contaminants that may not be associated with chemicals of potential concern at a site. Soil trip blanks are not employed frequently during soil investigations; aqueous trip blanks are a common component of groundwater sampling programs, however, and are discussed separately in the SOP for groundwater sampling

- Field blank - A soil sample analogous to a trip blank except that the field blank is opened at the site during the sampling activities. The need for, and frequency of soil field blanks and trip blanks should be evaluated on a project-by-project basis.

During the planning phase of a project, attention must be paid to the QA/QC sampling requirements of the involved regulatory agencies. For example, a soil sampling project located in the Los Angeles, California metropolitan area might need to address the sampling requirements or guidelines of one or more of the following agencies: 1) Regional Water Quality Control Board - Los Angeles Region, 2) Cal-EPA Department of Toxic Substances Control, 3) Los Angeles City Fire Department, 4) Los Angeles Department of Public Works, or 5) one of several local implementing agencies (LIAs) for the State Leaking Underground Storage Tank (LUST) Program.

3.3 SAMPLING METHODS

3.3.1 Solid-Barrel Samplers

Solid-barrel samplers typically are 1 to 6 inches in diameter and 6 to 60 inches long. They usually are constructed of steel or stainless steel and may be used with thin-walled liners that are placed within the sampler barrel. Liners typically are constructed of brass, aluminum, stainless steel, or synthetic materials such as polyvinyl chloride (PVC), polyethylene terephthalate (PETG), or Teflon®. Selection of an appropriate liner material must take into account the chemicals of concern and the proposed laboratory analyses (i.e., plastic liners may not be appropriate where samples will be analyzed for VOCs or SVOCs).

3.3.2 Split-Barrel Samplers

Split-barrel samplers (also known as split-spoon samplers) are the most widely used sampler in environmental investigations. Split-barrel samplers can be used with a wide variety of drilling methods and usually are constructed of steel or stainless steel. They are cylindrical in shape and are split longitudinally, forming two halves. Split-barrel samplers may be lined or unlined; as noted above, sample liners may be constructed of brass, aluminum, stainless steel, or various synthetic materials. Split-barrel samplers generally are available in 2-, 2.5-, 3-, 3.5-, and 4-inch outside diameters (OD); sampler lengths typically range from 12 to 60 inches.

The 18-inch long split-barrel sampler is most commonly used. Three, 6-inch long liners generally are used with this sampler.

Driving (hammering) is the most common method of collecting split-barrel soil samples. In most instances, a 140-pound drop hammer is used in accordance with American Society for Testing and Materials (ASTM) Standard D1586-84. The hammer may either be above ground or located downhole. Samples are collected by driving the sampler into undisturbed soil beneath the bottom of the borehole. The number of hammer blows (i.e., blow counts) are recorded for each 6 inch advance of the sampler. The density and consistency of the subsurface soils can be estimated using the hammer weight, drop, and blow count.

If the sampler cannot be advanced 6 inches following a reasonable number of blows (usually about 50), sampler "refusal" is judged to have occurred and further sampling at that depth interval is terminated. If "auger refusal" has not occurred, the borehole is advanced and another sample is collected.

After the sample has been collected, and the split-barrel sampler has been retrieved, the sample barrel is opened and the sample material is visually inspected and logged (see Section 4.0 for logging procedures). If the sample volume is inadequate, additional sample material can be collected from the underlying depth interval.

If the soil sample is retained for VOC or SVOC analysis, the selected sample liner is checked to ensure that a full sample was recovered, and covered with Teflon® tape and plastic end caps. In selecting sample material for testing, care should be taken to ensure that the retained material is representative of the sample interval, and does not represent sloughed material. Sloughed material is most likely to be present near the top of the sampler (or in the uppermost sample liner).

3.3.3 Thin-Walled (Shelby) Tube Samplers

The thin-walled tube (i.e., Shelby tube) sampler is a 30- or 36-inch long, thin-walled steel, aluminum, brass, or stainless steel tube equipped with a connector head. It is used in soft or clayey formations, where it provides better sample recovery than a split-barrel sampler, or where relatively undisturbed samples are desired. The most commonly used sampler has a 3-inch OD and is 30 inches long.

Thin-walled tube samplers typically are advanced by pressing the sampler or pushing without rotation. If the tube cannot be advanced by pressing, it may become necessary to drive the sample with drill rods and hammers. The tubes generally are allowed to stay in the hole 10 to 15 minutes to allow the buildup of skin friction prior to removal. Prior to retrieval, the tube is rotated to separate it from the underlying soil. After retrieval, the sample is inspected for adequate sample recovery. If sample recovery is inadequate, the sampling procedure may need to be repeated.

Following retrieval, the soil sample is described and recorded in the logbook and any disturbed soil material is removed from the end of the tube. The thin-walled tube is capped with a non-reactive material, such as Teflon® tape, for transport.

3.3.4 Continuous Split-Barrel Samplers

Continuous soil sampling can be performed with a specialized, 60-inch long, continuous split-barrel sampler that is advanced during rotation and advancement of a hollow-stem auger drill bit. To begin continuous sampling, the sampler is lowered into place at the base of the drill string using a wireline or drill rods. The sampler barrel is locked into place such that it protrudes from the drill bit. As the bit is advanced, the sampler is pressed into the formation. After the borehole has been advanced the full length of the sampler, the full sampler is retrieved and an empty sampler is lowered downhole to repeat the sampling process.

3.4 EXCAVATION SAMPLING

Collection of soil samples from an excavation may be necessary in the following situations: an underground storage tank has been removed; soil remediation by excavation and disposal is the chosen cleanup method; entry into an excavation is not permitted due to health and safety concerns; or typical drilling and sampling methods are incompatible with the known subsurface geology (e.g., underlying cobbles or boulders). Although collection of soil samples from the bucket of a backhoe, excavator, or gradall is not the preferred method, it sometimes may be the only option.

Collecting soil samples from the bucket of a backhoe almost always will result in a disturbed sample. Extra care to minimize further disruption of the sample may include:

- 1) Collecting a large enough volume of the desired soil in the bucket of the backhoe
- 2) Carefully lifting the bucket to the surface, being sure not to shake the bucket
- 3) Scraping away any loose material from the desired sample location in the backhoe bucket
- 4) Collecting a sample by driving in a solid-barrel sampler as described in Section 3.3.1 from the less disturbed soil located near the base of the bucket
- 5) Rapidly sealing and labeling the sample.

4.0 SOIL LOGGING

The description of textural, compositional, and other physical properties of soil samples, and resultant sample classification is an important skill in the field of environmental geology. The following logging procedures are intended to promote accurate and consistent soil sample description and classification. These procedures primarily are applicable to soil samples; bedrock logging is not included in this SOP due to the wider variation in bedrock characteristics, the many well-established (but often conflicting) classification schemes for different rock types, and the comparative infrequency with which bedrock logging is performed in environmental investigations.

4.1 SOIL DESCRIPTION AND IDENTIFICATION (ASTM STANDARD D 2488-93)

ASTM Standard D 2488-93 ("Standard Practice for Description and Identification of Soils [Visual-Manual Procedure]; ASTM, 1993) provides a standardized means of describing and classifying soil samples in the field. Based on observed sample characteristics, the standard also provides a flow chart for "identifying" the soil (i.e., the sample is assigned a Unified Soil Classification System [USCS] soil group name and symbol). With the exceptions noted below, and with the exception of project-specific requirements, ASTM Standard 2488-93 should be followed during environmental field investigations.

Application of the standard begins with the collection of a representative soil sample of sufficient volume and weight in the field. For example, the standard specifies that a soil sample with a maximum particle size equivalent to a No. 4 sieve should weight more than 100 g. The following descriptive information should be recorded, where applicable:

- Particle shape and angularity
- Color (a Munsell® color chart [GSA, 1991] should be used *instead* of the generalized approach presented in the ASTM standard)
- Odor
- Moisture
- HCl reaction
- Consistency
- Cementation
- Structure
- Range of particle sizes
- Maximum particle size
- Hardness
- Additional descriptive information, as warranted

Following the initial description, the soil should be categorized as "fine grained," if it contains 50% or more fines, or "coarse grained," if it contains less than 50% fines (fines are defined as silt- and clay-sized particles). For samples falling into the fine grained soil category (as described above), a series of easily-performed manual tests for dry strength, dilatancy, toughness, and plasticity are applied. The test results, along with the aforementioned descriptive information, are used to assign an appropriate USCS soil name. Coarse grained soil samples are named based on the descriptive information and the identification flow chart presented in the standard. The various USCS soil group names and symbols are summarized below:

Fine grained soils:

- CL - Lean clay
- ML - Silt
- CH - Fat clay
- MH - Elastic silt
- OL/OH - Organic soils

Coarse grained soils:

- GW - Well-graded gravel
- GP - Poorly graded gravel
- GM - Silty gravel
- GC - Clayey gravel
- SW - Well-graded sand
- SP - Poorly graded sand
- SM - Silty sand
- SC - Clayey sand

A copy of ASTM Standard D 2488-93 is attached to this SOP for reference (Attachment A).

4.2 M/B&A BORING LOG

Federal (USEPA, 1991) and State (DTSC, 1995) guidelines for environmental investigations require the preparation of graphic boring logs that document field observations noted during drilling and sampling. To facilitate the recording of accurate and complete field observations, and to ensure a consistent work product, M/B&A has developed a standard boring log format, a copy of which is presented as Attachment B. The log is divided into two principal parts, a header at the top of the log, and the main body of the log. The header is used to record information such as project name and number, site address, date, drilling and sampling methods, surveyed location/elevation, etc. The main body of the log is used to record information such as sample

descriptions, blow counts, sample recovery, depth, headspace screening, observed and inferred contacts between soil units, samples retained for laboratory analysis, etc.

Project-specific requirements and/or local agency requirements could require minor modification of the "standard" log format. Significant departures from the standard boring log format, however, should be made only after consultation with the Director of Geologic Services and the involved Project Manager.

5.0 REFERENCES

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ATTACHMENT A
ASTM STANDARD D 2488-93



Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)¹

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.*

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 1452 Practice for Soil Investigation and Sampling by Auger Borings²

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

D 2113 Practice for Diamond Core Drilling for Site Investigation²

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)²

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)²

3. Terminology

3.1 Definitions:

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 *clay*—soil passing a No. 200 (75- μ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

fine—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 *sand*—particles of rock that will pass a No. 4

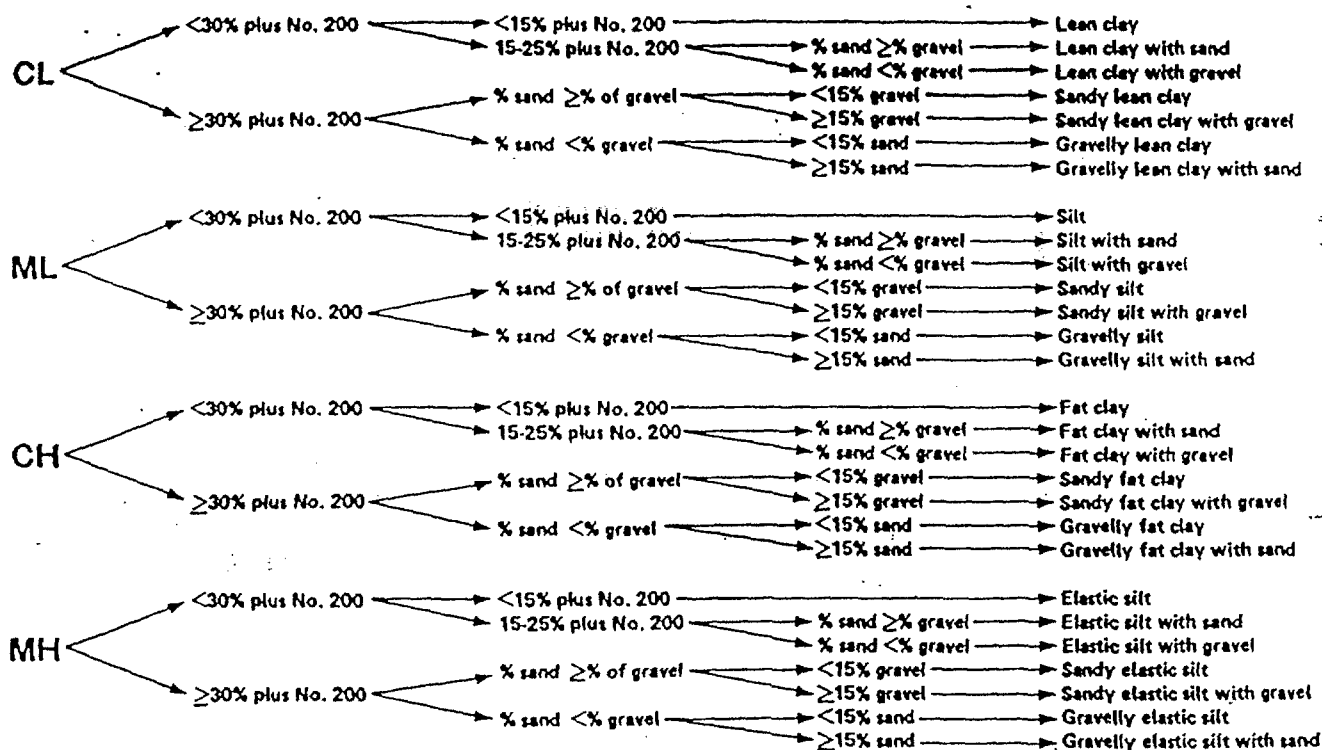
¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Sept. 15, 1993. Published November 1993. Originally published as D 2488 - 66 T. Last previous edition D 2488 - 90.

² Annual Book of ASTM Standards, Vol 04.08.

GROUP SYMBOL

GROUP NAME



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

(4.75-mm) sieve and be retained on a No. 200 (75-μm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-μm) sieve.

fine—passes a No. 40 (425-μm) sieve and is retained on a No. 200 (75-μm) sieve.

3.1.1.8 *silt*—soil passing a No. 200 (75-μm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the “A” line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

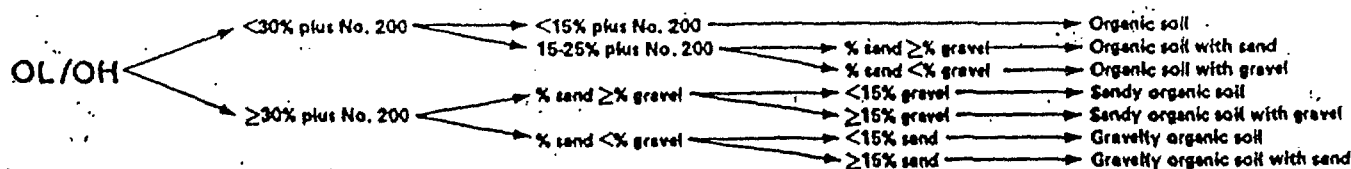
4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or

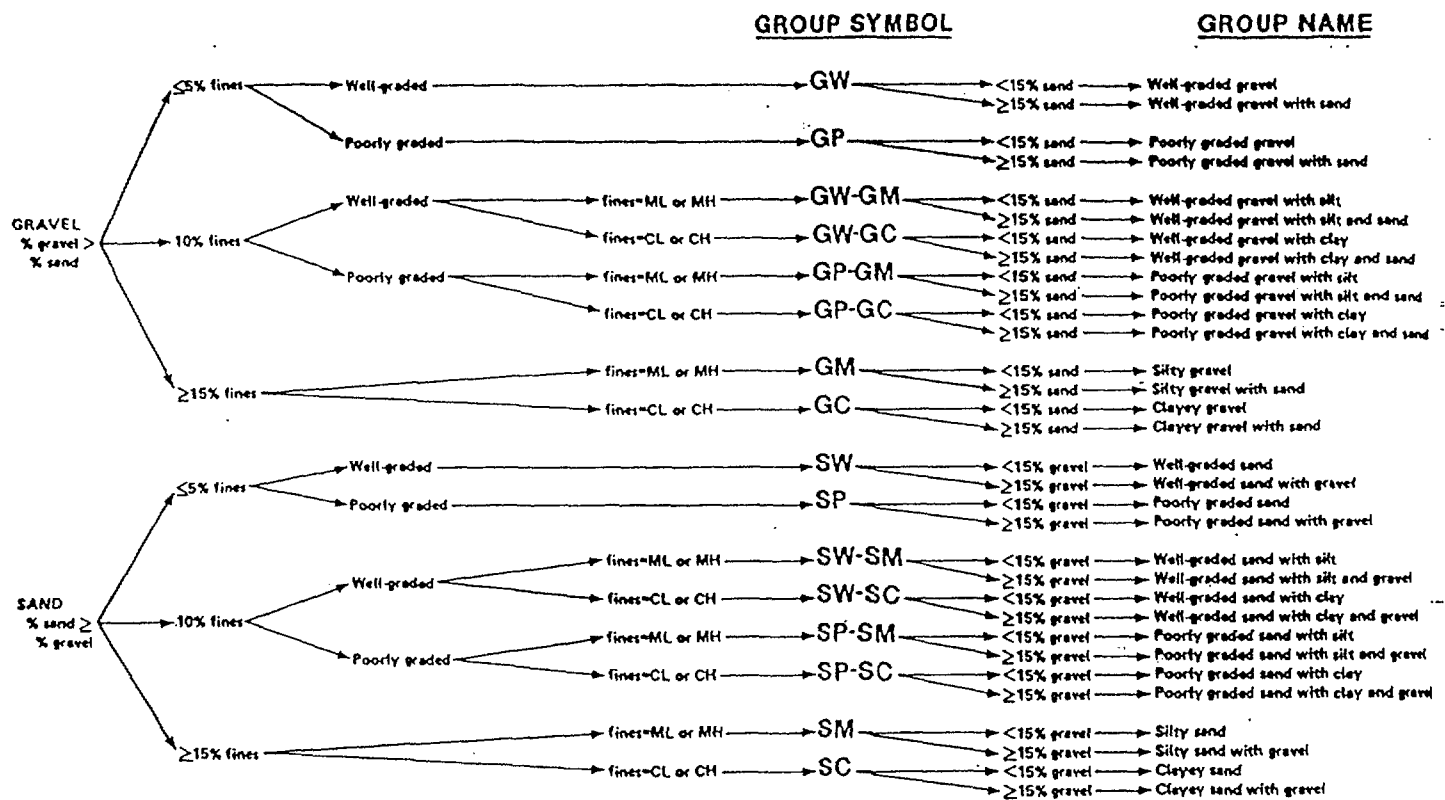
GROUP SYMBOL

GROUP NAME



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test

results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

6. Apparatus

6.1 Required Apparatus:

6.1.1 Pocket Knife or Small Spatula.

6.2 Useful Auxiliary Apparatus:

6.2.1 Small Test Tube and Stopper (or jar with a lid).

6.2.2 Small Hand Lens.

7. Reagents

7.1 **Purity of Water**—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 **Hydrochloric Acid**—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

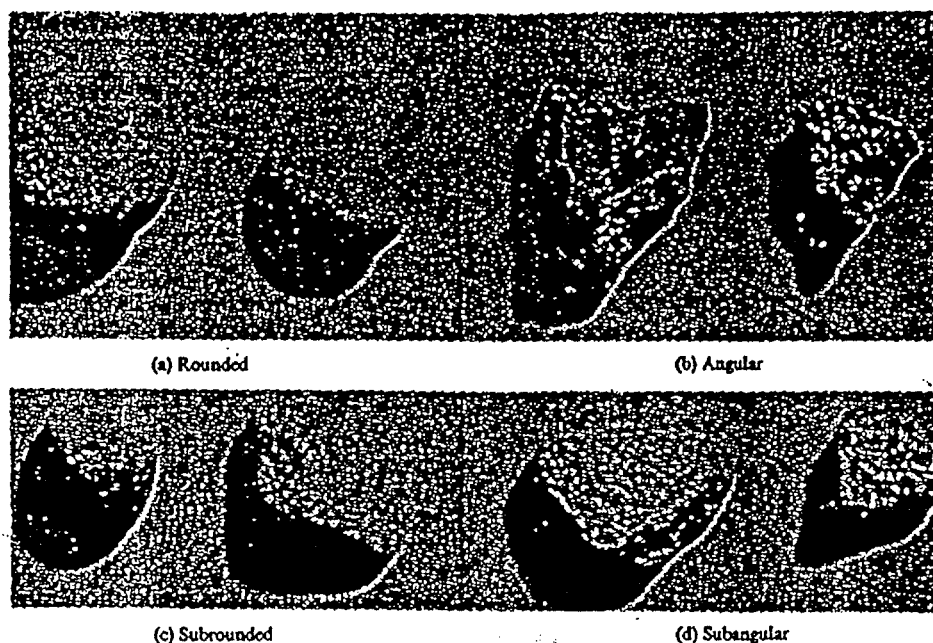


FIG. 3 Typical Angularity of Bulky Grains

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 Caution—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in

accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

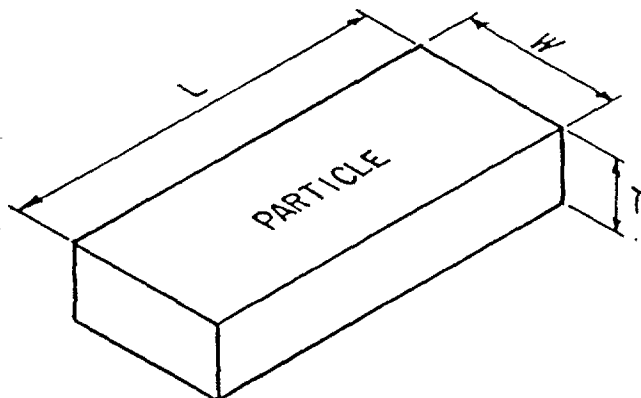
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

PARTICLE SHAPE

W=WIDTH
T=THICKNESS
L=LENGTH



FLAT: $W/T > 3$
ELONGATED: $L/W > 3$
FLAT AND ELONGATED:
—meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation.

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Fissured	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Blocky	Breaks along definite planes of fracture with little resistance to fracturing
Conchoidal	Fracture planes appear polished or glossy, sometimes striated
Crumbly	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

ation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more

fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/2 in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about 1/2 in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about 1/2 in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

the surface of the soil. Squeeze the sample by closing the palm or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

4.4 Toughness:

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads at the ends and roll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumble at a diameter of 1/8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

4.5 Plasticity—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 Identification of Inorganic Fine-Grained Soils:

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A 1/8-in. (3-mm) thread cannot be rolled at any water content
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 Identification of Organic Fine-Grained Soils:

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name. For example: "lean clay with sand, CL" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand. For example: "sandy lean clay, CL", "gravelly fat clay, CH", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
 - Gravel—fine, coarse
 - Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
- For intact samples:
 18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
 19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
 20. Cementation: weak, moderate, strong
 21. Local name
 22. Geologic interpretation
 23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

1. The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

2. The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

3.1 Identify the soil as a *well-graded gravel*, GW, or as *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

3.2 Identify the soil as a *poorly graded gravel*, GP, or as *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with intermediate sizes obviously missing (gap or skip size).

4. The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

5. If the soil is estimated to contain 10 % fines, give the soil identification using two group symbols.

5. The first group symbol shall correspond to a *clean gravel* or *sand* (GW, GP, SW, SP) and the second symbol shall correspond to a *gravel* or *sand* with fines (GC, GM, SC,

5. The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

6. If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

6.7 If the field sample contains any cobbles or boulders, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "gravel with cobbles, GM."

Report

6.1 The report shall include the information as to origin, the items indicated in Table 13.

NOTE 13—Example: *Clayey Gravel with Sand and Cobbles*, GC—about 50 % fine to coarse, subrounded to subangular gravel; about 30 % coarse, subrounded sand; about 20 % fines with medium plasticity; high dry strength, no dilatancy, medium toughness; weak

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray;

in-place density 106 lb/ft³; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to

100-mm) pieces of shale from power auger hole, dry, brown; no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two

possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the

percentage of fines is estimated to be between 45 and 55 %.
 symbol should be for a coarse-grained soil with fines
 the other for a fine-grained soil. For example: GM/ML
 CL/SC.

X3.1.2 A borderline symbol may be used when the
 percentage of sand and the percentage of gravel are estimated
 to be about the same. For example: GP/SP, SC/GC, GM/
 4. It is practically impossible to have a soil that would have
 a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil
 could be either well graded or poorly graded. For example:
 W/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil
 could either be a silt or a clay. For example: CL/ML,
 H/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-

grained soil has properties that indicate that it is at the
 boundary between a soil of low compressibility and a soil of
 high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect
 similarity to surrounding or adjacent soils. For example: soils
 in a borrow area have been identified as CH. One sample is
 considered to have a borderline symbol of CL and CH. To
 show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol
 should be the group name for the first symbol, except for:

CL/CH lean to fat clay
 ML/CL clayey silt
 CL/ML silty clay

X3.4 The use of a borderline symbol should not be used
 indiscriminately. Every effort shall be made to first place the
 soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and
 fine-grained material may be estimated by thoroughly
 shaking a mixture of soil and water in a test tube or jar, and
 then allowing the mixture to settle. The coarse particles will
 fall to the bottom and successively finer particles will be
 deposited with increasing time; the sand sizes will fall out of
 suspension in 20 to 30 s. The relative proportions can be
 estimated from the relative volume of each size separate.
 This method should be correlated to particle-size laboratory
 determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size
 particles placed in a sack (or other container) or sacks. Then,
 do the same with the sand size particles and the fines. Then,
 mentally compare the number of sacks to estimate the
 percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve
 size No. 4 material can then be estimated from the wash test
 (X4.3).

X4.3 *Wash Test (for relative percentages of sand and
 fines)*—Select and moisten enough minus No. 4 sieve size
 material to form a 1-in (25-mm) cube of soil. Cut the cube in
 half, set one-half to the side, and place the other half in a
 small dish. Wash and decant the fines out of the material in
 the dish until the wash water is clear and then compare the
 two samples and estimate the percentage of sand and fines.
 Remember that the percentage is based on weight, not
 volume. However, the volume comparison will provide a
 reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down
 lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbrevi-
 ated system may be useful to indicate the soil classification
 symbol and name. Examples of such cases would be graph-
 ical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the
 full name and descriptive information but can be used in
 supplementary presentations when the complete description
 is referenced.

X5.3 The abbreviated system should consist of the soil
 classification symbol based on this standard with appropriate
 lower case letter prefixes and suffixes as:

<i>Prefix:</i>	<i>Suffix:</i>
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in
 parenthesis. Some examples would be:

<i>Group Symbol and Full Name</i>	<i>Abbreviated</i>
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

X6. RATIONALE

Changes in this version from the previous version, Classification Symbols.
D 2488 - 90, include the addition of X5 on Abbreviated Soil

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ATTACHMENT B
M/B&A BORING LOG

